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VILLAGES AS ECOSYSTEMS

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Lecture No.2.2
Rural Technology Course

VILLAGES AS ECOSYSTEMS

Amulya Kumar N. Reddy

Introduction

Rural development, it will be recalled, is a socio-economic process directed towards the satisfaction of basic needs, the strengthening of self-reliance and harmony with the environment. It can be carried out at a number of levels - the country, the state, the district, the taluk/block, and the village. The village is the lowest level of aggregation and the smallest unit, but it is also the most natural unit since it has evolved by the spontaneous association of families. No wonder that villages display the stability and "permanence" which leads to the saying: "India's life is in its villages!"

Taking a village as the subject of analysis, the development of a village involves

(1) satisfaction of the basic needs of the villagers, starting from the needs of the neediest,

(2) strengthening the self-reliance of the village and its villagers, and

(3) harmony with the village environment.

Village development, therefore, depends upon an understanding of

(1) the basic needs of the village and its people,

(2) the extent of self-sufficiency of the village, and

(3) the interaction between the villagers and their environment.

The understanding of all these three aspects and of the complex and intricate inter-relationship between villagers, their needs and resources is faciliated by considering villages as ecosystems, where an ecosystem can be defined as "any area of nature that includes living organisms and non-living substances interacting to produce an exchange of materials between the living and non-living parts". In other words, it

is essential to study villages as ecosystems.

Unfortunately, few such studies exist, apart from the preliminary study of a Bengal village by Odend'hal in 1972. What follows is a brief report of a detailed study which has recently been made of Ungra village in Kunigal Taluk, Tumkur District, Karnataka State.

Ungra Village

The village of Ungra is located about 113 kms from Bangalore at a latitude of 12°49'N and 76°57'49" E. Its height above sea level is 670.6 metres and the mean annual rainfall, which is typical of the dry belt in Karnataka, is 727 mms. In December 1979, it had 149 households with a total population of 932. Ungra's total livestock population was 949 consisting of 460 cattle (111 bullocks, 143 cows, 93 calves and 113 buffaloes) and 489 goats and sheep (214 goats and 275 sheep). The area of the village is 360.2 acres.

Land-use pattern

The land-use pattern for the July to December 1979 croppin season is shown in Table 1. It is seen that the ratios of cultivated land to fallow land to grass land/marsh land to settlement are very roughly as 70:15:5:10. Further, viewing fallow land also as fodder-producing, along with grass land and marsh land, the ratio of pasture land (fallow+grass+marsh land) to cultivated land is 22:68, i.e., the area of pasture lands is approximately one-third the area of cultivated lands. This underlines the importance of pasture lands to the village ecosystem.

Cropping Pattern

The cropping pattern for the agricultural year 1979-80 is shown in Table 2 which has aggregated 20 entities into the category "others". Considering the kharif season (June/July t November/December), it is seen that paddy accounts for two-thi

of the cropped area, and paddy plus ragi (eleusine coracana) for 82.7% (about four-fifths) of the kharif area. Further, the cropped area for the summer season is only 8.2% of the kharif area; hence, the kharif season is virtually equivalent to the annual agricultural year, and the kharif yields are equivalent to the annual yields.

Above-ground Plant Biomass Productivity

The above-ground plant biomass productivity is shown in Table 3 - the average value is 6 tonnes/ha/year.

It is interesting to note (in Table 3) the biomass productivities of various entities compared with that of grass land. Paddy, Sorghum, Coconut and Sugarcane yield 40%, 22%, 84% and 55% greater productivity than grass land, but ragi gives 25% less productivity - these may be considered measures of the photosynthetic efficiencies compared to grass land. In fact, the weighted average (i.e., weighted for the areas shown in the cropping pattern) is only 28% greater than grass land - this indicates the poor return on human efforts in Ungra.

Table 3 also shows that paddy accounts for about half the above-ground plant biomass, and paddy+ragi+sugarcane+sorghum+coconut contribute about three-quarters of this plant biomass. All the crops taken together account for about four-fifths of the plant biomass compared to grass+marsh+fallow+shrub land which yield one-fifth of this biomass.

Disaggregation of Plant Biomass into Various Components:

The disaggregation of plant biomass into its various components has been carried out for all the crops - Table 4 shows the results for the main items in the ecosystem. The table reveals that the ratio of grain to straw for the main food crops: paddy, ragi and horsegram is about 1:2. Sorghum has an approximately 1:9 ratio of grain to straw because it is of the fodder variety grown solely for cattle.

Utilization of Components of Plant Biomass

Studies were also carried out to determine how the various components of the plant biomass of each crop were utilized in the ecosystem.

For example, the manner in which paddy biomass is utilized in the ecosystem is shown in Figure 1. Several points need to be noted. Firstly, all components of the plant biomass are made use of in the ecosystem. Secondly, perhaps the only unavoidable wastage of biomass is in the form of chaffy (or unfertilized grain) - this occurs to the extent of 1.7% of the total biomass. The avoidable wastage involves rice and its storage - this takes place to the extent of 3.6%. Thirdly, the striking feature of the biomass utilization pattern is that, in all the crops studied, there is no competition intended between human beings and livestock for the same biomass components, e.g., human beings live off the grain, and livestock off the straw.

Herbivore and Omnivore Consumption

The consumption of plant biomass by herbivores (cattle, goats and sheep) and omnivores (human beings) has been determined, but limitations of manpower and time prevented a study of biomass consumption by insects and birds.

Estimates of fodder consumption by livestock are presented in Table 5. The important observation here is that livestock derive about 60% of their fodder requirements from crop residues and 40% from grass, fallow and marsh lands. In other words, crop residues are important, but not enough - they must be supplemented by grazing from pasture land.

An idea of food consumption by human beings can be obtained from Table 6.

An estimate was also obtained of the quantity of paddy carried away by rodents during the harvest season. This was done with the help of a tribe which follows harvesting activity locating and excavating burrows to recover the paddy stored by rodents. Measurements on a sample of burrows revealed that there are, on the average, about 21 burrows per hectare with about 3 kgs of paddy per burrow. That is, the rodents take away about 64 kgs per hectare which works to about 10.2 tonnes of paddy per year for the Ungra ecosystem. The tribals claim, firstly, that they succeed in recovering almost all the grain taken away by rodents from the fields during harvesting, and secondly, that this grain is sufficient for their annual requirements. Hence, as far as the ecosystem is concerned, this 10.2 tonnes is being exported via rodents and tribals.

Energy Analysis

The energy flow through the ecosystem has also been analysed. The first stage of this analysis consisted of a previous study of the pattern of consumption of direct energy in Ungra village (Ravindranath et al 1980). The direct energy sources fall into two categories:- (1) animate sources, viz., human energy and animal energy, and (2) inanimate sources which can further be classified into commercial energy, i.e., electricity, diesel, kerosene, etc., and non-commercial energy, firewood, and vegetable wastes (crop residues)*. The distribution of these sources over various energy-utilizing activities in Ungra is shown in Table 7, and after conversion into a common energy unit, in Table 8.

The second stage consists of (1) measurements of the solar insolation throughout the cropping seasons, and (2) determinations through bomb calorimetry of the energy contents of the various types and components of plant biomass. The data thus obtained is under processing.

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*All cattle wastes in the Ungra ecosystem are used as manurial fertilizer; they are not burnt as fuel in the form of dung cakes.

The energy source-activity matrices (Table 7 and 8) are aggregated representations of the energy consumption pattern; in fact, the activities have been disaggregated into greater detail. For instance, energy consumption in agriculture (Table 9) has been resolved operation-wise - Table 10 gives the percentage of the total energy consumption of the two principal crops, paddy and ragi, going into critical agricultural operations.

Imports, Exports and Self-sufficiency

The situation with regard to imports, exports and consumption of food items is shown in Table 11. The position with regard to fuel is shown in Table 12, and with regard to milk in Table 13.

Animal Biomass

The measurements of animal biomass are presented in Table 14.

Ecosystem Operation

From the data obtained on the production of plant biomass, its disaggregation into various components, the consumption of these components by herbivores and omnivores, and the imports and exports, etc., it has been possible to represent the operation of the Ungra village ecosystem by means of the usual type of diagram with the symbols used by Odum (1971).

Figure 2 is a highly aggregated version of the materials flow through the ecosystem.

Land-human beings-livestock Ecosystem

One of the most important conclusions emerging from the ecosystem diagram is that the agricultural village of Ungra (with the population densities shown in Table 15) is principally a land-human beings-livestock ecosystem with the category "l

including water and nutrients. The three main components of the ecosystem, viz., land, human beings and livestock, are in a delicate balance with energy mediating their inter-relationships.

The fundamental logic of the ecosystem can be oversimplified as follows: To satisfy Ungra's basic need of cereal foodgrains, the majority of Ungra's adult human beings must engage in agriculture, which not only requires land but, in the absence of agricultural mechanization, draught power. The latter comes from draught animals. But, draught animals need fodder which can be obtained either from pasture land or from crop residues. With land being scarce because of high population densities, the minimum possible land must be allocated for grazing - hence, as much fodder as possible must be obtained from crop residues, and only the fodder essential to supplement the crop residues must come from pasture lands. Since both human beings and cattle must depend on crops - and on different components of the crop biomass - <u>all</u> components of crop biomass are vital to the functioning of the ecosystem.

Cereal grains must be cooked before they become food for human beings, and cooking requires fuel. The traditional fuel in Ungra is firewood and the cooking is carried out in mud stoves or "chulas". Hence, there is a strong correlation between the total cereal consumption and firewood consumption. The implication is that the basic need of food can be satisfied only, if in addition to foodgrains, there is also the requisite amount of firewood from trees or shrubs.

The basic need for shelter is met either with traditional mud-walled thatch-roofed houses or with burnt-brick-walled mangalore-tiled-roofed houses. The former require thatching material and the latter fuel.

Water is essential - for domestic purposes and for agriculture. Domestic water is obtained with expenditure of human energy, and the water for irrigation is from three sources:-

(1) direct rain on to the crop-land

(2) canals which are fed by tanks that store rain-water

(3) wells from which groundwater must be lifted with the expenditure of energy.

Another input for agriculture is fertilizer - and this comes predominantly from farmyard manure obtained from cattle dung.

Thus, the land-human beings-livestock ecosystem operates with the aid of fuel, water and farmyard manure.

Crop Varieties

As long as agriculture is achieved through such ecosystem the traditional strategy has been to produce all the various crop biomass components - and not only the grain - in precisel the ratios required to sustain the population of human beings and cattle. This is in sharp contrast to the green revolution strategy which exclusively emphasises the grain in its dwarf varieties. By yielding a lower percentage of crop residues, the fodder output of the dwarf varieties is reduced - and this either necessitates a separate production of fodder, or more pasture land, or a replacement of animal draught power with mechanized equipment (e.g., power tillers/tractors) which then creates a demand for fuel (currently, oil).

Crop varieties, therefore, must be chosen to suit the agricultural ecosystem into which they are introduced. Howeve appropriate a crop variety may be for one ecosystem, it is likely to be totally inappropriate for other ecosystems which are basically different. In particular, varieties selected fo

conditions of low population density, large percentage of pasture land, and oil-fuelled mechanized agriculture may be quite unsuitable for agricultural ecosystems like Ungra. This point is borne out by the Ungra data which shows that the high-yielding varieties* (HYV) of paddy give about 12% more grain at the cost of 6% less fodder and 117% more wastage (Table 16).

Open, Dependent Ecosystem

The situation with regard to food is such that only in the case of milk does the ecosystem have enough net production (production minus export) to meet consumption requirements (Table 11). This does not mean that the ecosystem cannot meet its requirements, the fact is that it does not - this is an "irrationality" of the ecosystem which needs comment later..

For instance, about half the total paddy production is exported - this is tantamount to dedicating about a third of the ecosystem's cropland for exports. The effect is that the ecosystem becomes highly dependent on imports for pulses, oil-seeds and jaggery (crude sweetener) - in fact, the village imports almost all its requirement of oilseeds.

The situation is not much different with regard to the fuel requirements of the ecosystem.

As can be seen from Table 8, about 90% of the inanimate energy requirements of Ungra come from firewood. The present study has shown that only half of this firewood comes from internal sources, the remaining half has to be imported from outside the ecosystem (Table 12). Further, only 23% of these imports are obtained by firewood-gathering expeditions, with 77% being purchased as a commercial commodity. Also, the bulk of the firewood, about 93% of the firewood, is obtained as

*In fact, these varieties are not really as high-yielding (in Ungra agriculture) as they ought to be, because of inadequate and/or improper application of inputs such as water, fertilizer, pesticides, etc.

twigs, leaves, etc., i.e., without the felling of trees and deforestation.

In addition, Ungra imports electricity at the rate of about 38,500 KWH/year (Table 7) but about 67% of this is consumed by its agricultural pumpsets for water-lifting. The remaining electricity is shared between its industry (8%) and its domestic needs, which are mainly lighting (25%). However, only 20% of its households are electrified.

Ungra also imports kerosene at the rate of 3.8 litres/month/household (Table 7).

Thus, the Ungra ecosystem is neither closed nor self-sufficient - in fact, it is highly dependent on the external world for several vital items including food and fuel

Land-use Pattern

(a) Carrying Capacity with respect to Cereal Crops

Defining A_{CL} as the area (in ha) devoted to cropland, P_i as the productivity of the cereal i (in kg/ha/year), E_i as the energy content of crop i in kcal/kg and R_H as the nutritional requirement in kcal/capital/day, it is obvious that N_H, the number of human beings who can be supported by the ecosystem is given by

$$N_H = \frac{A_{CL}\ P_i\ E_i}{R_H} \qquad \ldots\ldots\ (1)$$

By rearrangement, it is possible to define the carrying capacity, C_i, with respect to the crop i (in persons/ha of cropland), in the following way

$$C_i = \frac{N_H}{A_{CL}} = \frac{P_i\ E_i}{R_H} \qquad \ldots\ldots\ (2)$$

In case of ragi, which is one of the staple cereals in Ungra, the measurements of the present study have shown that

P_{ragi} = 1241 kg/ha and E_{ragi} = 3723 kcal/kg. By assuming a nutritional requirement of R_H = 2800 kcal/capita/day, it follows that C_{ragi}, the carrying capacity of the Ungra ecosystem is 4.5 persons/ha of cropland. In fact, the ecosystem is presently carrying 4.4 persons/ha of cropland.

This simple calculation shows that, due to increases in population, the Ungra ecosystem is currently supporting a population density which is only slightly less than its carrying capacity with respect to ragi. Even this carrying capacity has been calculated from the observed ragi productivity for one season, and may be lower in bad (agricultural) years. In fact, the approach of the actual population density to the carrying capacity for ragi was clearly appreciated by local wisdom because the process of abandoning ragi as the main crop began several decades ago.

Since then, the change in the cropping pattern has been in favour of paddy which has a much higher carrying capacity. The present measurements have given the following values : P_{paddy} = 2469 kg/ha/year and E_{paddy} = 3560 kcal/kg, which when inserted in equation (2) yield an ecosystem carrying capacity for paddy of 8.6 persons/ha which is almost double that for ragi.

But, the change-over (from ragi which was a rain-fed crop) to paddy has made the ecosystem dependent on the import of water. This import is through a chain of seven tanks supplied by a large reservoir - the Marconahalli reservoir - built on the Shimsha river. Even this linkage of the Ungra ecosystem to the reservoir has not assured it of a guaranteed water supply every year. The point is that the reservoir itself collects rain water from a large catchment area, and if the rains fail in the catchment region, then water is not let out to the chain of tanks and the ecosystem does not get sufficient water for paddy. In such bad years, the Ungra farmers except those who have pumpsets, have no alternative except to fall

back on ragi in which case they suffer food scarcity - perhaps even starvation.

What has been described here is a principle (Reddy 1979) which is being revealed in almost every one of ASTRA's investigations : the traditional has ceased (or is rapidly ceasing) to be adequate, but the modern is invariably inaccessible except to a few. This is a central dilemma of development, and this dilemma also defines the crucial role of science and technology, which generate a variety of adequate and accessible options.

(b) Bunds*

It is well know that earthen bunds are built to retain the water necessary for paddy. The present studies showed that in the Ungra ecosystem the bunds occupy 10% of the area cropped with paddy. At first, it was thought that this large percentage was due to the fragmentation of holdings, but this turned out not to be the case. The small "mean free path" between bunds is mainly because of the primitive surveying technology. This traditional approach consists of constructing temporary bunds surrounding small rectangles/squares of land, allowing water in, identifying as depressions the portions where water stands and then scraping the land until water stands uniformly. If modern surveying and levelling technologies are employed, then the "mean free path" between bunds can be increased significantly. With a smaller percentage of land occupied by bunds, the production of paddy can be correspondingly increased.

(c) Summer Crop Area

The summer crop area is only about 8% of the kharif area. This is primarily due to the lack of water, but represents a tremendous under-utilization of capacity. To increase the potential of the ecosystem, it would be necessary either to

*Bund: Any artificial embankment (The Shorter Oxford English Dictionary on Historical Principles (1978) Clarendon Press, Oxford).

decrease imports by water conservation along with an optimized utilization of the Marconahalli reservoir + tanks system or to enhance the raising of ground water with inputs of energy.

Livestock

(a) Number of Draught Animal Pairs (DAP) and Human to Draught Animal Pair Ratio

Measurements have been made of P_{DAP}, the productivity of ploughing by draught animal pairs (in ha/DAP). A preliminary value for the ecosystem has been found by time and motion studies to be about 1.64 ha/DAP. From these measurements of P_{DAP}, the number of draught animal pairs in the ecosystem, N_{DAP}, can be predicted to be

$$N_{DAP} = \frac{A_{CL}}{P_{DAP}} \qquad \text{..... (3)}$$

which when combined with equation (1) yields the ratio, N_H/N_{DAP}, of human beings to draught animal pairs:

$$\frac{N_H}{N_{DAP}} = \frac{P_{DAP}\, P_i\, E_i}{R_H} \qquad \text{..... (4)}$$

Since draught power must be available for the crop with the lowest productivity, the values of P_{ragi} and E_{ragi}, viz., 1241 kg/ha and 3723 kcal/kg respectively, can be inserted in equation (6). In addition, if P_{DAP} = 1.64 ha/DAP as mentioned above and R_H = 2800 kcal/capital/day, it turns out that N_H/N_{DAP}, the ratio of human beings to draught animal pairs should be 7.41.

Unfortunately, this expectation is not at all borne out by observation, because the observed ratio is 16.79 if only bullocks are used for draught purposes. But, it is well known that there is a belt in Southern India where cows are also used for ploughing - a common practice in the Ungra ecosystem. If cows are also counted in calculating the observed ratio of human beings to draught animal pairs, an observed value of 7.34 is obtained with which the predicted value is in agreement to within 1% (Vaidyanathan 1978).

Similarly, using equation (3), the number of draught animal pairs (counting bullocks and cows) is predicted to be 128 in comparison with the observed value of 127 - again, good agreement.

The reason why cows are used for ploughing in this part of the country, and not in other parts, has not yet been established. But, it is almost certain to be related to the hardness of soils, as modified by the soil moisture, because this hardness defines, through an inverse relationship, the power requirements for ploughing. As the hardness of soils increases from the softest soils, it seems necessary to deploy more and more powerful sources for ploughing, i.e., to ascend the following heirarchy of power sources: human beings (with hoes), buffaloes, cows, bullocks, horses, power tillers and tractors.

(b) Weight of Ungra Cattle

Cattle in Ungra are much smaller and lighter than cattle in western countries - the average weight of bulls is about 230 kg and that of cows is about 193 kg (Table 14). However, observations in Ungra have shown that draught animals are used for ploughing only for about 20 days in a year. When an item of equipment has such a low load factor (number of working hours per year), the obvious strategy is to incur on it as little expenditure as possible. This is what the Ungra farmer

do with their draught animals. Thus, their lean and hungry draught animals represent their optimization of costs and benefits of feeding cattle - in fact, it is common knowledge in the Ungra region that farmers increase their fodder supply to draught animals before the ploughing season in order to increase their strength.

(c) Human: Cattle Ratio

The total number of cattle, N_{CT} required by the ecosystem is obviously given by

$$N_{CT} = N_B + N_C + N_{Bf} = 2\ N_{DAP} + N_{Bf} \quad \ldots\ldots\ldots\ldots\ (5)$$

where N_B, N_C and N_{Bf} are the numbers of bullocks, cows and buffaloes respectively. The number of buffaloes can be obtained as follows from the data on milk consumption in Ungra

$$N_{Bf} = \frac{N_H\ Mf_{MBf}}{Y(1-f_{ME})\ f_L} \quad \ldots\ldots\ldots\ldots\ (6)$$

where M is the daily per capita milk consumption, f_{MBf}, the fraction of total milk production obtained from buffaloes, f_{ME}, the fraction of the ecosystem's milk that is exported, f_L, the fraction of milch animals that are lactating, and Y is the average daily milk yield.

Combining equations (1), (3), (5) and (6) and rearranging terms, the following result is obtained:

$$\frac{N_{CT}}{N_H} = \left[\frac{2\ R_H}{P_{DAP}\ P_i\ E_i} + \frac{Mf_{MBf}}{Y(1 - f_{ME})f_L}\right] \quad \ldots\ldots\ (7)$$

Using the ragi values for P_i and E_i, and the following observed values for the terms on the right-hand side : M = 0.055 litres/capita/day, $f_{MBf} = 0.70$, $f_{ME} = 0.27$, $f_L = 0.36$, and Y = 1.41 litres/buffaloe/day, the required cattle to human ratio

is calculated from equation (7) to be 0.37 which agrees quite well with the observed ratio of 0.39.

Energy

(a) Draught Power

The central role of animal energy in a traditional agricultural ecosystem is based on the crucial importance of the ploughing operation and its requirement of draught power. Though unequivocal evidence has not yet been obtained, it appears that draught power is a critical constraint on Ungra's agriculture. It seems that an augumentation of draught power is essential for increasing the carrying capacity of the ecosystem. There are many options for achieving this objective.

The first option is to increase N_{DAP}, the number of draught animal pairs. This option has two implications:- firstly, an increased capital expenditure -- in fact, it is to avoid this financial burden that Ungra farmers do not increase their holdings of draught animals; and secondly, an increased requirement of fodder. But, the number of draught animal pairs is fodder limited. The fodder-constrained limit on the number of draught-animal pairs which can be supported by the ecosystem depends on:- (1) the areas of cropland and pasture land, (2) their productivities with respect to fodder production, and (3) the fraction of total fodder allocated to draught animals. If, for instance, the quantity of pasture land fodder is constant, and also the area devoted to crop production and the fraction of the total fodder allocated to draught animals, then the number of draught animal pairs can only be increased by increasing the productivity of fodder production through crop residues. If this cannot be done because of draught power constraints, then the limit in draught animals has been reached.

The second option is to increase, P_{DAP}, the productivity of draught animal pairs, i.e., the number of hectares which can

be ploughed by a draught animal pair. This productivity can be increased in three ways:- (1) by increasing the power output of draught animal pairs, i.e., by using stronger draught animals, (2) by decreasing the hardness of the soil, and (3) by increasing the mean speed of ploughing. Each of these ways of increasing productivity has implications.

The use of stronger animals implies either more expensive animals and/or feeding them better. But, as pointed out above, the low load factor of draught animals does not justify either more expensive animals or better feeding. Such a justification requires an increase in the load factor, i.e., a diversification of the use of draught animals so that, apart from ploughing, a number of year-round productive outlets for draught power are developed. In fact, there were in the past a number of such traditional uses of draught animal power - bullock-carts, water-lifting, milling, crushing (e.g., sugarcane crushing), oil extraction, etc., but mechanized equipment has been making all these capabilities redundant.

The decrease of soil hardness is best achieved by an increase of soil moisture, but this requires irrigation at the proper time and in the proper quantity.

An increase in ploughing speeds can be achieved by decreasing the number of times the draught animal pairs must turn direction because they tend to slow down at these turns. This implies an increase in the mean free path (or spacing) between bunds - but this can only be achieved by improved surveying and levelling technology.

The third option is to replace draught animal power by mechanized equipment (power tillers and tractors) fuelled with inanimate energy. If, as at present, oil is used as the inanimate energy source for power tillers and tractors, then the ecosystem becomes dependent on imports and therefore more vulnerable to escalations in the price of oil. Apart from this

dependence on fuels, the costs of these categories of equipmen
must be considered.

Much deeper analysis is required before one of these options, or a combination of two or more of these options, is chosen.

(b) Human Energy

As in the case of draught animal energy, human energy al appears to be a critical constraint in agriculture, particula for the transplanting and harvesting operations. The precise nature and extent of this constraint is under intensive study and therefore a discussion of this aspect will be deferred.

(c) Domestic Fuel

The present consumption of fuel in Ungra is 442 tonnes/y or 7.5 kg/household/day, or 0.44 tonnes/capita/year, and as pointed out above, about 50% of this has to be imported from outside the ecosystem. The question, therefore, arises: can the ecosystem be made self-sufficient with respect to cooking fuel? Several approaches can be followed.

Firstly, more fuel can be grown within the ecosystem. To produce the 262 tonnes that is now imported, about 5.24 to 10.48 ha of land are required, assuming that fast-growing trees yielding 25 to 50 tonnes/ha/year are grown. The only land available today in Ungra is the 15.8 ha of grass land, but if this land is used for growing fuel, there will be a serious reduction in fodder production. However, a possibili is a two-tier fuel-cum-fodder forest where both fuel and fodder are grown.

Secondly, the efficiency of cooking stoves, which is presently less than 10%, can be approximately doubled leading to a halving of fuel consumption. Since fuel imports constitute approximately half the total consumption of fuel in Ungra, the approach of doubling stove efficiencies can lead

to fuel self-sufficiency.

Lastly, cattle wastes can be anaerobically fermented to generate biogas for cooking. It is estimated that Ungra's cooking needs can be met with the dung from 390 cattle. This means that if the dung from all Ungra's 460 cattle are processed in biogas plants, there will be excess gas available for other purposes. Hence, the biogas approach will not only provide a far more convenient cooking fuel, but will eliminate the need for fuel imports <u>and</u> relieve the ecosystem of providing firewood for cooking fuel. Only 14% of the total ecosystem requirement of 522 tonnes, i.e., about 73 tonnes, will then be required for other purposes.

(d) <u>Fuel for Brick-burning</u>

Apart from domestic needs, another significant demand for firewood is in brick-kilns. About 20 tonnes of firewood were used in February/March 1980 for brick-burning. This firewood was obtained by felling 23 trees, i.e., 0.5% of the tree population of the ecosystem. It appears that brick-burning is far more responsible than cooking (which is largely done with twigs) for rapidly reducing the tree resources of the Ungra ecosystem. Fortunately, it has been demonstrated (Jagadish 1979) that burnt-bricks are quite unnecessary for house construction and that unburnt compacted mud-blocks can serve the same purpose. Thus, the demand for fuel from brick-kilns can be eliminated.

(e) <u>Energy for Lighting, Water-lifting, etc.</u>

Electricity can easily be generated from biogas engine-cum-generator sets, which means that the excess biogas available (after meeting the cooking energy needs) can be used to provide electric lighting and eliminate kerosene imports. And, pumpsets can be run on producer gas generated from wood or charcoal - the requirement is about 3 tonnes of wood/pumpset/year. In fact, with the replacement of firewood for

cooking and of burnt-bricks for house-construction, the demand on firewood is so drastically reduced that it becomes available in plenty for alternative uses such as running pumpsets.

In conclusion, therefore, the plant biomass resources of the village ecosystem can be shown to be abundant enough to meet its present and future energy requirements.

Directions of Recent Work

A major limitation of the present study of the Ungra village ecosystem is that the functioning of the ecosystem has been aggregated over an agricultural year. In this process, information on the time-variation of various features of the ecosystem has been lost. But, this time factor is crucial. For instance, the timeliness of many agricultural operations, e.g., ploughing, has profound effects on biomass productivity. Hence, it is vital to monitor the functioning of the ecosystem throughout the course of an agricultural year and determine the variations of material and energy inputs and outputs. It is this task which is now being undertaken - in fact, the data collection has almost been completed.

Another serious limitation of the work described here is that, following most ecological studies, human beings have been considered as a single, homogeneous category. This approach may be perfectly justified in the case of "primitive" societies, but in "civilized" societies, one or more sections of the society are "predators" on the other section(s). In these situations, human beings have to be differentiated into groups, and unless this is done, it will not be possible to understand certain aspects of the behaviour and functioning of the ecosystem. For instance, its imports and exports may appear "irrational" - Ungra exports 50% of its paddy and imports all its oilseeds. This task of categorizing Ungra's human beings into landless, marginal, small, medium and large farmers, and of tracking the inter-category transactions is now

in an advanced stage of completion. It appears to provide a new unification of ecology and economies, where both the economic influences on ecosystem behaviour as well as the ecological constraints on economics are clearly brought out.

The third direction in which the present work needs to be developed would involve the forecasting of the effects of various types of interventions. For instance, what would be the changes in the ecosystem if biogas replaces firewood for cooking? Similarly, there is a need to anticipate future demands on the ecosystem. For all such types of questions, it may be useful to develop simulation techniques. This approach is also being pursued.

Conclusion

The study of the village agricultural ecosystem described here has revealed some of the important inter-relationships involved in its functioning. In fact, it has shown that there is a great deal of rationality in the ecosystem as demonstrated by the agreement between many calculated and observed ratios pertaining to important parameters of the system. This shows that these parameters are not matters of chance, but they emerge from an inherent logic. An understanding of this logic relating to the complex linkages, particularly between human beings, livestock, land, energy, and water, and between food, fuel and fodder, should be a pre-condition for intervention into village ecosystems. Otherwise, the actual results of interventions may be totally different from what is intended. Thus, an ecosystem approach must be the basis of rural development; for, it necessarily leads to the so-called "holistic" and "integrated" viewpoints.

This lecture is based on the following two papers:

(1) 'An Indian Village Agricultural Ecosystem - Case Study of Ungra Village Part I : Main Observations' (N.H. Ravindranath, S.M. Nagaraju, H.I. Somashekar, A.Channeswarappa, M. Balakrishna, B.N. Balachandran and Amulya Kumar N. Reddy with the assistance of P.N.Srinath, C.S. Prakash, C. Ramaiah and P. Kothandaramaiah)

(2) 'An Indian Village Agricultural Ecosystem - Case Study of Ungra Village Part II : Discussion' (Amulya Kumar N. Reddy)

presented at the International Conference on 'Energy from Biomass', November 4-7, 1980, Brighton (U.K.)

Table 1: Land-use Pattern

		Hectares	%
	Cultivated (22)*	243.7	67.7
Crop land			
	Fallow (1)	47.0	13.0
		290.7	80.7
Grass land (3)	....	15.8	4.4
Marsh land (1)	....	15.4	4.3
Plantation (coconut, fuel) (2)		0.8	0.3
Water bodies (2)	....	0.2	-
Settlement (Houses, Roads etc) (4)		37.3	10.3
		360.2	100.0

*Number in brackets refers to number of items aggregated.

Table 2: Cropping Pattern - AY 1979-80

Crop	Kharif June/July-Nov/Dec. Area(ha)	%	Summer Area	
1.(a) Paddy (local)	126.7	52.0	-	
(b) Paddy (HYV)	33.7	13.8	-	
	160.4	65.8		
2.Ragi	41.1	16.9	10.1	5
3.Sorghum	8.7	3.6	-	
4.Sugar-cane	7.1	2.9	7.1	3
5.Horsegram	6.7	2.7	-	
6.Coconut	4.6	1.9	-	
	228.6	93.8	17.2	8
7.Others (20)	15.1	6.2	2.7	1
Total	243.7	100.0	19.9	10

Table 3: Above-ground Plant Biomass Productivity

	Entity	Productivity (tonnes/ha)	Ratios	Production (tonnes)	%
1.	Crops				
	1(a). Paddy (local)	6.9	1.38	791.5	41.4
	1(b). Paddy (HYV)	7.1	1.42	216.5	11.3
				1008.0	52.7
1.2	Ragi	3.8	0.76	111.6	5.8
1.3	Sorghum	6.1	1.22	50.1	2.6
1.4	Sugar-cane	27.3	5.46	194.0	10.1
1.5	Horsegram	1.9	0.38	13.3	0.7
1.6	Coconut	9.2	1.84	97.4	5.1
1.7	Others	-	-	24.2	1.3
				1498.6	78.3
2.	Grass land	5.0	1.0	73.7	3.9
3.	Fallow land	5.3	1.06	249.6	13.1
4.	Marsh	5.0	1.0	76.7	4.0
5.	Shrub	12.5	2.5	14.4	0.7
				414.4	21.7
	Total average	6.0		1913.0	100.0

Table 4: Disaggregation of Above-ground Plant Biomass

Crop	Grain (%)	Straw (%)	Oth
1. Paddy	36.68	61.58	1.
2. Ragi	32.34	67.66	-
3. Sorghum	11.87	88.43	-
4. Horsegram	37.83	62.17	-
5. Sugarcane	Stem 72.26%		
	Leaves 27.74%		
6. Coconut	Nuts (Shell+husk)	21.98%	
	Leaves	61.41%	
	Inflorescence	4.84%	
	Copra	11.77%	

Table 5: Fodder Consumption by Livestock

	Total	Bullocks	Cows	Calves	Buffalo	Goat/s & Sheep
Paddy straw	571	180	207	17	167	-
Sorghum grain	1	1	-	-	-	-
Sorghum straw	49	20	23	-	6	-
Grass + Fallow + Marsh land	400	78	91	-	124	107
	1021	279	321	17	297	107

Fodder from crops = 621 (60.8%)

Fodder from grass Land + Fallow land + Marsh land = 400 (39.2%)

Table 6: Food Consumption of Human Beings

	Annual consumption (tonnes)	Consumption (capita/day)
Rice	143.19	0.42 kg
Ragi	89.88	0.26 kg
Pulses	52.25	0.15 kg
Oil	3.00	8.75 gms
Jaggery	15.22	44.74 gms
Sugar	2.25	6.63 gms
Milk	18710(lit)	55 ml
Meat	5.11	15.02 gms

Table 7 : Energy Sources & Activities in Ungra

Source	Units	Agri-culture	Domes-tic	Light-ing	Indu-stry	To
1. Human	hours	218,941	612,133	-	132,116	963
1.1 Man	"	(143,549)	(168,671)	-	(110,135)	(42
1.2 Woman	"	(75,392)	(305,304)	-	(19,426)	(40
1.3 Child	"	-	(138,158)	-	(2,555)	(14
2. Animal	"	36,654	-	-	3,381	40
3. Firewood	kg	-	411,636	-	68,085	479
4. Agro-waste	"	-	42,808	-	-	42
5. Electricity	KWh	25,894	-	9,524	3,000	38
6. Kerosene	litres	-	144	5,383	756	6
7. Diesel	"	32	-	-	-	
8. Coal	kg	-	-	-	1,500	1

Table 8 : Ungra Energy Source-activity Matrix ($\times 10^6$ kcals/annum)

Source		Agri-culture	Domestic	Light-ing	Indu-stry	Total
1.	Human	51.0	119.9	-	31.7	202.6
(1.1.	Man)	(35.9)	(42.2)	-	(27.5)	(105.6)
(1.2.	Woman)	(15.1)	(61.1)	-	(3.9)	(80.1)
(1.3.	Child)	-	(16.6)	-	(0.3)	(16.9)
2.	Animal	84.3	-	-	7.8	92.1
3.	Firewood	-	1,564.2	-	258.7	1,822.9
4.	Agro-waste	-	162.7	-	-	162.7
5.	Electricity	22.3	-	8.2	2.6	33.1
6.	Kerosene	-	1.3	48.3	6.8	56.4
7.	Diesel	0.3	-	-	-	0.3
8.	Coal	-	-	-	9.9	9.9
		157.9	1,848.1	56.5	317.5	2,380.0

Total energy = 2.766 KWht/year = 7578.5 KWht/day

= 8.13 KWht/cap/day

Table 9 : Energy requirement in Agriculture

	Man hours	Woman hours	DAP ho
Paddy	690	349	163
Ragi	328	284	179
Sorghum	271	-	66
Sugarcane	2237	1180	175
Horsegram	102	59	132
Coconut	216	-	66

Table 10 : Energy requirement of Critical Operations in Agriculture

1. Paddy

   Man - Transplanting (35%), Harvesting + Threshing (23%)

   Woman - " (34%), " + " (43%)

   DAP - Ploughing (41%), Manuring (27%)

2. Ragi

   Man - Ploughing (24%), Transplanting (21%)

   Woman - Transplanting (42%), Harvesting+Threshing (51%)

   DAP - Ploughing (45%), Manuring (25%)

Table 11 : Self-sufficiency in food

	1 Prodn.	2 Ex-ports	3 % Expor-ted	4 Avail-able for food	5 Im-ports	6 Con-sump-tion	$\frac{4}{6}$(%)
Rice	370	176	47.4	124	18	143	87.4
Ragi	36	1	2.8	35	55	90	39.1
Pulses	6	-	-	6	46	52	11.5
Oil seeds	0.4	-	-	0.4	2.6	3	3.8
Jaggery	52	48	92	4	11	15	27.2
Milk(in ltrs)	25897	6935	26.8	18961	-	18961	100

Table 12 : Fuel Sources

From Ecosystem		tonnes/yr
Coconut	....	61
Other crops	....	2
Trees (Twigs)	....	172
Trees (Felled)	....	20
Shrubs	....	5
		260
Imports from outside ecosystem		
FW (Bought)	....	203
FW (Gathered)	....	59
		262
Total	....	522

Table 13: Milk Production and Consumption in Ungra Agricultural Ecosystem

Milk Animal	Total Number	Milking	Average milk yield per day (litres)	Daily milk production (litres)	Annual milk production (litres)
Cows	119	28	0.77	21.6	7, 884
Buffaloes	97	35	1.41	49.35	18,012.75

a. Total milk production/day : 70.95 litres

b. Average Quantity of Milk exported: 19.00 litres (26.78%)

c. Total Milk consumed in the village/day : 51.95 litres(73.22%)

d. per capita consumption of milk: 0.05574 litres

e. Milk production exported: 26.77%

Table 14 : Animal Biomass in Ecosystem

Animals	Population	Number weighed	Total weight of the animal weighed (in kgs)	Average weight per animal (in kgs)	Estima total in the ecosys (in kg
I. Cattle					
Bullocks	111	50	11,455.3	229.10	25,43
Cows	143	74	14,260.5	192.70	27,55
Buffaloes	113	45	9,545.0	212.11	23,96
Calves	93	29	2,546.4	87.80	8,16
Total	460	198	-	-	85,12
II. Sheep/goat					
Sheep	275	185	5,797.0	31.33	8,61
Goat	214	32	672.8	21.02	4,49
					13,11
			Total of I & II		98,23

Table 15 LAND - MAN - LIVE STOCK ECO SYSTEM

Population density	2.59 persons/ha (total)
	3.82 persons/ha (crop land)
Human : Livestock	1 : 0.98
Human : DAP	7.34 : 1
DAP Population density	0.52 DAP/ha (crop land)
	1.92 ha crop land/DAP
Cattle Population density	1.28 c/ha (total)
Human : cattle	2.03 : 1
Cattle : Goats/Sheep	1 : 0.94
Human : Goats/Sheep	1.91 : 1
G/S Population density	1.36 G/S/ha (total)

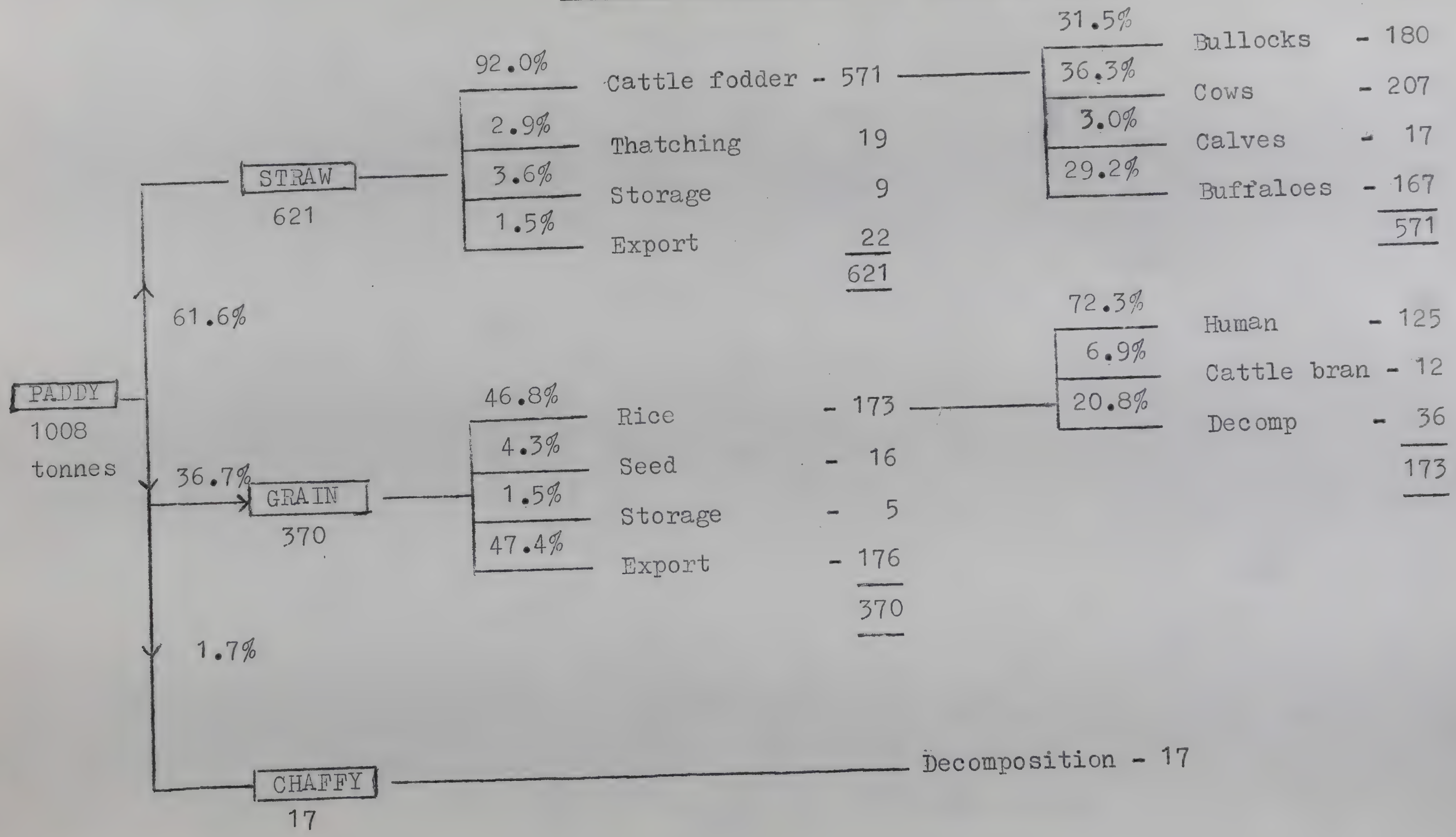
Human	Cattle	Goats/Sheep	Land
1	0.49	0.52	0.39 (total)
			0.26 (crop land)
1	0.5	0.5	0.4 (total)
			0.3 (crop land)

Table 16 <u>HYV VERSES LOCAL PADDY</u>

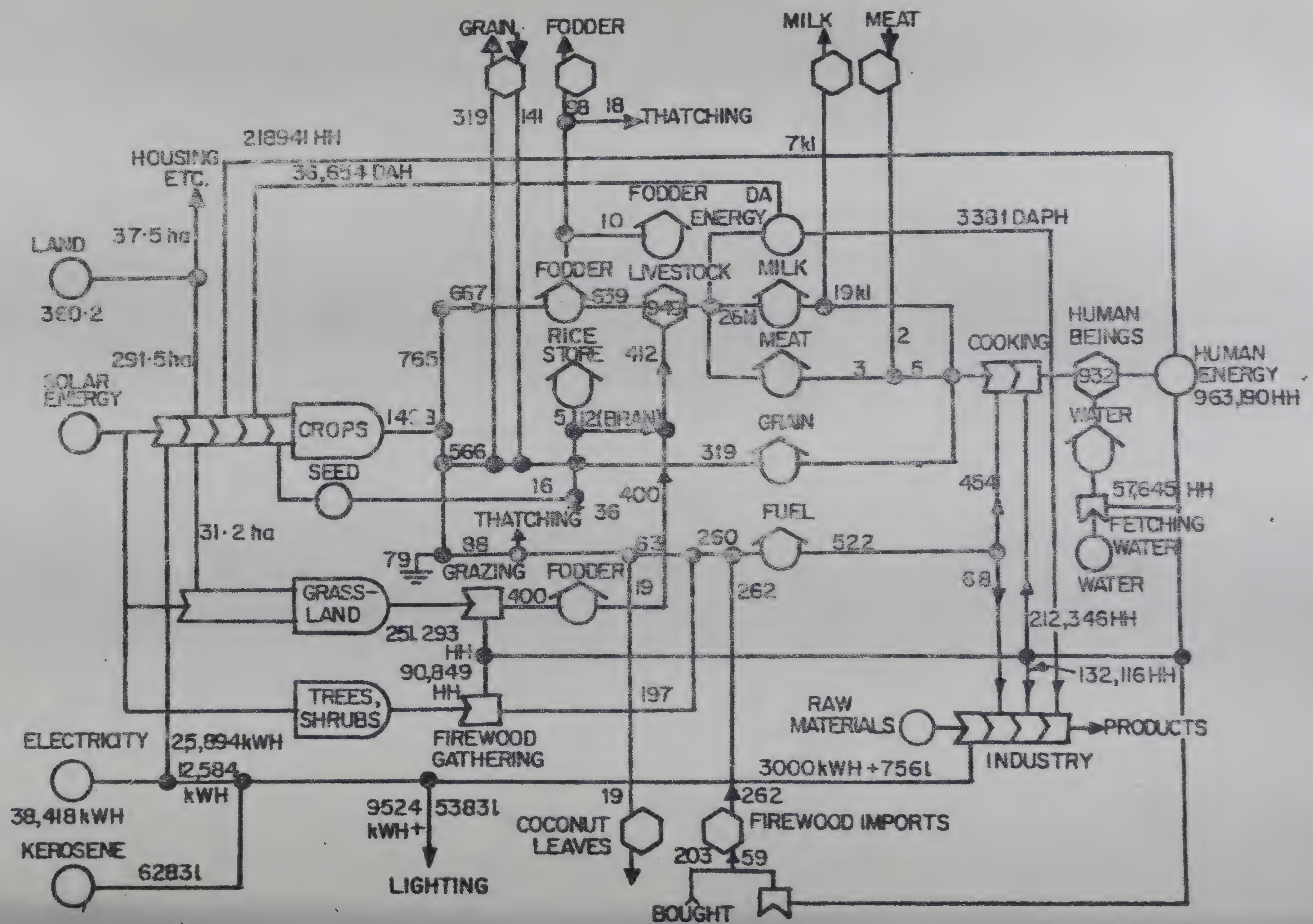
	Grain		Straw		Chaffy	
	%	kg	%	kg	%	kg
H Y V Paddy	40	2820	57	4067	3	210
Local paddy	36	2469	63	4322	1	97
cf. Local		+351 (+12.4%) more grain		-255 (-5.9%) less fodder		+113 (+116.5%) more waste

+ More fertilizer

Figure 1: UTILIZATION OF PADDY BIOMASS



THE UNGRA AGRICULTURAL ECOSYSTEM



PROGRESSIVE ENLARGEMENT OF DRY LAND MULBERRY CULTIVATION IN MYSORE DISTRICT

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Lecture No. 2.4
Rural Technology Course

PROGRESSIVE ENLARGEMENT OF DRY LAND MULBERRY CULTIVATION IN MYSORE DISTRICT

Although the beginnings of silkworm rearing and mulberry cultivation date back to the days of Tippu Sultan, the size of activity in this regard remained modest over a long stretch of time. In 1923-24 the area under mulberry in the entire Princely State of Mysore (essentially in the four districts of Bangalore, Kolar, Mandya and Mysore) was barely of the order of 30,000 acres, and the bulk of cultivation was under irrigated conditions. It was only in the black cotton soils of Chamarajanagar and T. Narasipur taluks in the Mysore District that dry land mulberry had been developed over modest surfaces adding up to less than 10000 acres. The raw silk produced was being absorbed by the silk reeling and weaving cottage units in the adjoining areas of Yelendur and Kollegal (centres reputed for traditional silk fabrics). The picture remained almost unchanged until the late thirties.

Towards the end of 1937, under private initiative a modern fairly large-sized filatures unit was established in T.Narasipur, and this gave a big fillip to the spread of dry land mulberry cultivation in the surrounding areas. Thus began a new phase in the land use pattern as well as rural economic life of the region. Mulberry cultivation started taking over lands that were under ragi and jola.

It was most fortuitous that the Second World War broke out (in September 1939) soon after the Filature Unit went into production. The demands for silk filatures fabricated in the

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Unit shot up beyond all expectations, with the orders from t then Government of India themselves constituting the most important component. (Itally and Japan, the traditional suppliers of parachute silk to the British were in the opposite camp and the British had to look for alternate sour to procure parachute silk for their war needs. The quality silk produced by the T.Narasipur Unit proved most satisfacto for the purpose). Domestic silk filatures enjoyed boom conditions inside the country with the cessation of imports from Italy and Japan. The Governments at the centre and the State instituted a series of measures to stimulate expansion of silk filatures, the more important of them being special loans to the filature units and obsorption of the entire production by the Government at the centre at attractive prices. In 1940-41 a centre for improved foreign race silk worm seed production was set up in Biligiri Rangan Hills. Another silk filatures unit was installed in Kuderu in Chamarajanagar talu Silk filature production in the State went up from 2200 kg in 1937 to 136000 kg in 1944-45. The area under mulberry cultiv tion went up in the same period from 30000 acres to 80000 acres, practically the entire increase being confined to the dry lands of T.Narasipur and Chamarajanagar.

It is to the credit of the then government of the Princel State of Mysore that soon after the cessation of the war, measures were taken to check the expansion of mulberry, realing the implications of diverting the lands under staple grai for this purpose. However, the policy was short lived.

Soon after the integration of the Princely State into the Indian Union and the launching of 'planned economic development' in the country, there was a revival of interest in expanding mulberry silk production; and since the First Five Year Plan period, the Governments at the Centre and the State have been vigorously pursuing a policy of expanding production. Over the past three decades, incentives and assistance for mulberry cultivation and silkworm rearing have been progressively strengthened.

By the end of the First Plan, in 1966 the area under mulberry cultivation in the State had reached a figure of 130000 acres, and as a consequence of the reorganization of the States and entry of Kollegal Taluk into Mysore District of the State, the total area under mulberry stood at 155000 acres in November 1956. The rates of increase in the area under cultivation over the subsequent periods are as under:

Year	Area under Mulberry (in acres)
1950-51	80,000
1956-57	155,000
1961-62	185,000
1968-69	200,000
1974-75	260,000
1975-76	268,000
1977-78	275,000

(K. Puttuswamiah: Loc. Cit.)

It is believed that currently the total area under mulberry in the State is of the order of 300,000 acres.

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A massive programme (aided by the World Bank) for a substantial expansion of mulberry cultivation and silkwork rearing through extending these operations to the other districts of the State is reported to be in full swing.

What is important to note is that about three-fourths of the total area under mulberry cultivation is under rainfed conditions, and the largest concentrations of rainfed mulberry is in the district of Mysore, especially in the taluks of T.Narasipur, Kóllegal and Chamarajanagar.

Area under Mulberry: 1975 - 76

District	Rainfed	Area Irrigated	Total
Mysore	159,232.5	5,282.5	164,515.
Bangalore	13,472.5	22,385.0	35,857.
Kolar	11,000.0	23,200.0	34,200.
Mandya	14,110.0	14,110.0	28,220.
Other districts	2,842.5	3,345.0	6,817.
	200,657.5	68,332.5	268,980.

(Dept. of Sericulture, Government of Karnataka)

It is seen that in 1975-76 Mysore District alone accoun for about 165,000 acres of land under mulberry out of a tota of 269,000 acres in the entire State (62 per cent); and abou 159,000 acres out of this area (96 per cent) were under rain conditions.

Over the past four decades some 150,000 acres of arable land that were being utilised earlier for cultivating ragi ar

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jola (together with other food crops through inter-mixing and rotation) have been diverted to the planting of mulberry trees. One has to give serious thought to the implications of this development to the eco-system and rural life of the region.

In the specific context of the Southern Part of Mysore District, the focus would be on the Chamarajanagar Taluk and the adjoining parts.

The following table shows the spread of mulberry over the past decade in the different taluks of the Mysore District.

Area under Mulberry cultivation (in acres)
Mysore District (Southern Part)

Year	Chamarajanagar	Yelendur	Nanjangud	Gundlupet	H.D. Kote
1969-70	35,440	12,040	11,903	3,858	-
1970-71	35,713	12,080	11,880	3,943	-
1971-72	36,293	11,875	12,328	4,080	-
1972-73	37,690	11,750	21,443	3,620	-
1973-74	37,570	10,893	20,463	4,988	-
1974-75	40,162	13,003	20,865	5,625	-
1975-76	42,528	13,213	20,315	6,200	-
1976-77	43,558	13,300	21,500	6,813	25
1977-78	42,552	15,153	21,575	7,170	16
1978-79	45,053	13,700	23,525	7,525	25

Rest of the District

Year	Kollegal	T.Narasipur	Mysore	Other Taluks
1969-70	25,925	23,908	2,493	-
1970-71	26,398	24,475	2,445	-
1971-72	26,700	24,523	2,447	5

(contd...)

1972-73	26,700	25,338	2,450	5
1973-74	23,460	26,135	2,455	-
1974-75	37,028	28,800	4,230	60
1975-76	32,198	28,398	4,480	23
1976-77	32,495	27,300	4,487	80
1977-78	33,098	27,400	3,830	60
1978-79	35,073	27,613	3,698	133

(Compiled from data published by the Bureau of Economics and Statistics, Govt. of Karnataka).

(The irrigated component, as already seen, is hardly of significance. In 1978-79 the total mulberry area under irrigation just added up to 2274 acres: Yelendur - 1002 acre Kollegal - 852 acres; T. Narasipur - 188 acres; and Chamarajanagar - 32 acres).

The decade that is just over has witnessed not only sizeable expansion in the traditional mulberry areas of Kollegal, T.Narasipur, Chamarajanagar and Yelendur but an impressive thrust into the neighbouring taluks of Nanjungud and Gundlupet. The areas undermulberry, entirely rainfed, have doubled in these taluks over the decade.

Given the pace and vigour with which the Department of Sericulture is developing the infrastructure facilities in Nanjangud Taluk in terms of government mulberry farms, grainages, extension services, etc., and the attractive market prices for raw silk, it would appear that there would be a substantial spread of rainfed mulberry cultivation in the taluks of Nanjangud and Gundlupet, unless the process is effectively checked in time.

It is of vital interest to the people of the region to reflect on the implications of this drift, that is being actively supported by government policies and programmes.

Yields in terms of mulberry leaves under rainfed conditions in the region are reported to be in the range of 3000-3500 kg per acre, in contrast to yields of irrigated mulberry of the order of 10,000 kg per acre. Therefore, theoretically, the levels of existing mulberry production in the region could be realised on about one-third of the existing area. If cultivation is undertaken under irrigated conditions; and two-thirds of the existing land under mulberry could be retrieved and utilised for other forms of agricultural activity. The proposition, however, is purely theoretical.

The fact is that some 90,000 acres of land that were earlier under ragi and jola (and associated pulses and oil seeds) are today committed to mulberry plantation under monoculture; and more and more of the arable lands of the region are being brought under mulberry. The plant is of the traditional variety suited to rainfed cultivation, with a life span of 15-25 years in distinct contrast to the new variety - M5 propagated in the irrigated areas, with a life span of 5 years.

Taking note of the remarkably high yields of irrigated mulberry in comparison with that under rainfed conditions, one would expect the official policy to consist of a phased withdrawal of rainfed mulberry cultivation as the areas under irrigated mulberry expand. However, the World Bank aided Crash Programme of the Union and State Governments for mulberry silk development does not envisage any such contraction of rainfed mulberry. It is pointed out that only the

new plantations in other parts of the state would be under irrigated conditions. There is no indication either of any effective check on further expansion of dry land mulberry i the region. The evidence is to the contrary.

At the macro-levels of the State Economy and the econo of the Nation, the arguments advanced in defence of mulberr silk development are in terms of the gains achieved through industrialisation and export earnings. However, in recent years, the export earnings of silk fabrics are ranging betw Rs.5 to 6 crores whereas the annual value of raw silk produ in the State is of the order of Rs.80 crores. (K.Puttaswama Loc. Cit - p.641 and p.672). Export earnings are seen t be a tiny fraction of the total value of silk produced in t state itself; and even the existing areas under irrigated mulberry could contribute towards more than doubling the export earnings.

It has to be explicitly recognised that an overwhelmin part of the silk produced in the State is serving only the domestic markets. And therefore it is pertinent to examine the nature of demands that the industry is meeting by commit ing such large areas of arable land under mulberry cultivat

The end product viz., pure silk fabric is essentially an item of luxury consumption for the affluent in the countr largely concentrated in the urban centres. Pure silk fabric are the highest priced among the different types of textile

fabrics. The end product of the industry itself does not command any social priority (although markets for pure silk fabrics are reported to be enjoying boom conditions) and does not warrant diversion of land from uses that serve mass interests.

It is pointed out, however, that the industry commends itself from the point of view of the high employment and income generation in the mulberry growing areas, by promoting a series of forward linkages in the region itself. In addition to the direct employment in mulberry cultivation, sizeable employment opportunities are afforded in the subsequent phases of cocoon production and silk reeling (on charaka and cottage basins) in the rural homes. A recent study (1980) undertaken at the Institute of Social and Economic Change (ISEC) by Shri A.R. Rajapurohit and Shri K.V. Govindaraju, entitled "A Study of employment and income in Sericulture" presents an interesting analysis in this regard. Based on the survey conducted in a rainfed area in Chamarajanagar Taluk and an irrigated area in Sidlaghatta Taluk (Kolar District), the study has offered the following Table (Page III) summarising the results:

Employment and income generation per acre of Mulberry.

	Rainfed area		Irrigated area	
	Employment labour days	Value added	Employment labour days	Value added
	Rs	Rs	Rs	Rs
1. Mulberry leaf production	44.17	-	45.72	-

2. Coccon production	122.51	1639	143.50	63
3. Silk reeling on Charakha	55.86	260	121.89	5
4. Silk reeling on cottage basin	47.73	783	99.23	16
Total (1+2+3)	222.54	1899	312.91	68
(1+2+4)	214.41	2422	290	79

Total employment and income generated by cultivating mulberr one acre of dry land viz. 214 labour days in an year and Rs. 1899 (or Rs.2422) respectively are indeed impressive, especially in comparison with the corresponding figures for ragi cultivation viz. 41 labour days and Rs.322 (pages 40 an 61 of the study).

There is no denying that the handsome gross proceeds realised through the sale of pure mulberry silk fabrics at the final consumer point sets off cash flows all down the line, and after the absorptions at the higher levels (retaile wholesaler, manufacture of fabrics and raw silk trader), sizeable cash flows descend to the mulberry region and get distributed to the persons engaged in silk reeling, cocoon production and mulberry cultivation in the region.

The benefits in terms of cash incomes to these persons and their families in the region are no doubt striking especially in comparison with those in the region engaged in other pursuits. The question, however, is what do these benefits of employment and money incomes represent in terms o

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real income and quality of living to the region.

It would be most meaningful to preface an answer to this question by reproducing the stimulating observations made in the "introductory part of the ISEC study (page 9):

> "As a matter of fact, cotton crop in India during the pre-British period was providing employment to the cultivators not only at the crop growing stage but also at the crop processing stage. The cotton picked up by the women labour of the cultivators families was brought home and was cleaned and was further ginned by the same women using a crude wooden board and a wooden rod. Further, the cotton yarn was spun in the same household on a crude type of charakha by the women members of the family. Thus the employment generated upto the spinning stage at least was concentrated within the farm household itself. Even at the stage of dyeing and weaving the cloth, the employment and income were generated usually in the same village among the specialised artisan classes. Probably this idea of cotton crop generating very high level of employment and income among the cultivators families influenced Mahatma Gandhi to uphold the cause of hand spinning and handloom weaving industries in the rural areas".

This admirable example of the forward linkages of cotton cultivation benefiting the rural families of the cotton growing region in terms of income and employment has added merit of

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producing an end product that directly meets the basic needs of clothing of these very families and others in the region (as well as the needs of similar families outside the region As against the income and employment generated through successive stages from cotton cultivation to production of cloth, there is a corresponding real income.

Moreover cotton is a seasonal crop that enters into annual cropping patterns (in cotton growing areas) in rotati with other appropriate seasonal crops. And in the total cropping systems of a region, generally a meaningful coordin tion is established between cotton and food crops in land us planning.

Mulberry and mulberry silk present a totally different picture. The end product of the activities in mulberry cult vation, silkworm rearing and silk reeling has no relevance t the consumption needs of the region. The materials as well as labour effort of the region are utilised for final output that are absorbed elsewhere; but the benefit to those engage in these activities in the region are in the form of <u>money incomes</u>. It is natural to reason out that apart from the direct benefit to these persons, the consumer demands emanating out of these money incomes should have an all roun salutary effect on the region through the familiar multiplie processes. The reality however in the rainfed mulberry area is altogether different.

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Expansion of mulberry cultivation has taken place not by developing new virgin lands for the purpose. It has been brought about by planting mulberry on the dry arable lands that were earlier under ragi or jola. Farmers who are now growing mulberry and buying ragi or jola with their money incomes were raising ragi or jola on these very lands were selling the produce after stocking adequately for their family consumption. At the area under mulberry has gone on expanding, correspondingly the area under ragi and jola has gone on falling.

In Chamarajanagar Taluk, already the area under mulberry has surpassed the area under ragi and jola. In 1977-78, the corresponding figures were 38998 acres and 37668 ares. (Mysore District at a glance 1977-78 - Bureau of Economics and Statistics). Over the past four decades, population of the taluk has more than doubled but area under ragi and jola and correspondingly production have halved (yields of millets under rainfed conditions have been stagnating at low levels all over the country). In recent years, the taluk is importing heavier and heavier quantities of foodgrains from outside to meet the market demands essentially emanating from those engaged in the expanding mulberry and raw silk sector.

Here is a situation wherein rising market demands for staple foodgrains are not only not being matched by rising supplies but the very factors accounting for rising demands are responsible for the falling supplies. Demands for

foodgrains are rising because of expanding mulberry cultivat and supplies of foodgrains are falling because of mulberry cultivation. And what is disturbing is that this phenomenon is fast spreading into the neighbouring taluks of Nanjangud and Gundlupet.

In the earlier section, it was seen how intelligent the traditional systems of crop production were on the rainfed lands and how effectively pulses (red gram, broad beans, cowpea, horsegram and Bengal gram) and oilseeds (gingelly, niger, and groundnut) were raised through inter-mixing and crop rotation on the ragi and jola fields. It was also seen how the green crop residues served as previous cattle feed and the dried residues as fuel. The expansion of mulberry cultivation under monoculture has meant not only a decline in the production of staple grains but of pulses and oil seeds as well.

Enthusiasists of regional specialisation might plead that the advantages of employment and income generated in the rainfed mulberry areas need not be given up as long as the food demands of these regions could be adequately met out of imports from other parts. This presupposes the availability of surpluses elsewhere. However, at the macro-level of the country itself millets, pulses and oilse production has been stagnating at low levels over several decades (in sharp contrast to wheat and rice).

Production of Millets, Pulses and Oilseeds in India

(in million tonnes)

	1955-56	1960-61	1970-71	1975-76	1978-79
Millets	6.77	6.69	6.93	7.91	7.09
Pulses	11.71	12.73	11.82	13.04	12.17
Oilseeds*	5.50	6.87	9.26	9.91	9.55

*Groundnut, rapeseed and mustard, sesamum, linseed and casterseed.

Per capita availability of pulses per day has fallen in the country from 70.4 grams in 1956 to 44.8 in 1979).
(Economic Survey : Government of India - 1979-80).

When a region which was at one time surplus in millets, pulses and oilseeds turns into chronic deficit in a context where the country is facing shortages in all these times, the effect is only one of aggravating the shortages.

Generation of employment and income in rural areas in lines that do not add to the outputs needed by the people of the region but on the contrary brings about a fall in these outputs cannot qualify itself as a socially desirable policy. It is of the greatest urgency that men in authority re-examine the policy of continuing mulberry cultivation under rainfed conditions.

The most serious aspect of the spread of mulberry on the dry lands is its ecological implications in terms of the effect on soils. The variety suited to rainfed cultivation

and propagated since long in the region is the one that has a life span of 15 to 25 years. The cultivation is under monoculture with no other plant species to be found on the vast stretches of mulberry land. The plant is deep rooted, descending to about 10 feet below the ground surface. The soils are treated annually with organic manure, but the supplies of organic manure are dwindling in the region. And increased application of chemical fertilisers is being encouraged to force higher yields in terms of leaves, which is harvested in entirety. Not a single lead is left on the plant to dry itself and fall to the ground. There is just no possibility of mulching and humus formation, nature's mechanism of rebuilding and enriching soils. And the fact that the plant is deep rooted only means that the soil nutrients at deeper levels are being mined for feeding the leaves.

These lands were for centuries being maintained in a rich state of soil fertility by the earlier generations with the cropping patterns and cultivation systems described earlier - characterised by mixed cropping and crop rotation, rich application of green and organic manures, rest to the soils and sundrying of the soils periodically, and so on.

The lands are now under the monoculture of mulberry subjected to soils mining to promote an industry that is essentially intended for meeting the luxury consumption of

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the affluent. As early as in 1939 Jacks and Whyte wrote:

> "A nation cannot survive in a desert, nor enjoy more than a hollow and short lived prosperity if it exists by consuming its soil. This is what all the new lands of promise have been doing for the last hundred years, though few as yet realize the full consequences of their past actions or that soil erosion is altering the course of world history more radically than any other war or revolution.
>
> The new worlds could not have been developed without the help of foreign capital in the form of money, goods and services, most of which was paid for by exporting soil capital - an apparently harmless procedure at a time when fertility was reckoned in terms of the inexhaustible supplies of plant-food minerals in virgin soils. Physically fertility was but little understood, still less was it realised that physical and biological characteristics were much more important forms of soil capital, more easily wasted and more difficult to restore than chemical characteristics".
>
> "Movements of capital have been an outstanding feature of the modern world. They may truly be said to have been one of the mainsprings of progress, but capitalism has never seriously concerned with its repurcussions on the humus content and structure of soils. Novertheless, the repurcussions have been shattering in their effort and can no longer be ignored."
>
> (The Rape of Earth - Faber and Faber, 1939)

What soil capital is being preserved on the rainfed mulberry lands to be entrusted to the posterity is a question that has to be answered by those that possess the scientific knowledge on the subject.

2.4

ENERGY PLANTATIONS

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Lecture 3.4.2

Rural Technology Course

ENERGY PLANTATIONS

We have been studying various alternatives to meet energy requirements of the future inconsistent with certain objectives like minimizing dependence on non renewable resources like coal and oil and minimizing environmental hazards of resources like nuclear. To meet the increasing demands on energy, which is supposed to reach around 700 billion units of electricity by 2000, we already need new solutions. Add to it the fact that we have to substitute for oil and coal and this gives us the magnitude of the problem we are facing or rather going to face. Any way, it is a good sign that groups of people/engineers/energy specialists discuss in seriousness the alternate resources, the pros and cons of using coal or nuclear, environmental problems of large impounded reservoirs for hydro plants. This results in at least channeling of some R and D funds into certain non conventional resources and might ultimately lead to an optimal planning meeting ecological, environmental and social constraints with an objective function of not merely optimizing energy expenditure or budget but improving the general conditions of people in vital sectors like food, shelter, health, clothing and employment.

One of the interesting possibilities seems to be using wood as a fuel in a boiler and generating steam and electricity for different end uses. Amongst the various alternatives of this has many attractive features like

a) its heat content is similar to that of Indian coal (or slightly less than that of coal)

b) technology needed is not new and can be system engineered quickly

c) we have a wide range of solutions like

(i) wood charcoal (fuel)

(ii) wood team electricity (small scale plants)

(iii) wood electricity (centralised plants)

(iv) wood producer gas

d) In most of the situations, we can also consider the possibilities of recovering many by products like oils, esters, organic compounds etc.

e) A small size plant might produce steam and electricit and the foliage plus grass from the plantations can b used as fodder and the remainder might be processed through a biogas digester to yield manure and gas.

f) A large size plant will provide employment, increase cultivation in forest areas and improve ecological conditions.

g) Capital costs are low

h) Sulfur content in wood is low (.1). This means lesser maintenance.

i) Ash can be reused as fertilizer in the plantations. Hence disposal is easy.

j) The resource is renewable. It has a total time constant of 3-8 years only for each cycle.

k) Carbon balance of the earth is not affected. More oxygen will be produced.

l) Controlled afforestation implies better quality and quantity control. Presently, forest department could not prevent thefts and deforestation. Statistics does not reveal the quality of forests. With additional cash flow into forestry, proper control is feasible.

m) Forests are well dispersed over the country so it will reduce transmission costs because needs of region can be met from the nearby forests as far as possible.

n) Village wood-lots can be developed as energy plantations. We can get steam and electricity for local use. Twings and barks can be used by local people for their cooking needs. (Now they have to travel far off to collect fire wood needed for cooking). Grass and leaves can be used as fodder and manure. In addition, biogas can also be generated. Intense diary activities and agro processing can be started with the help of the decentralized powr system.

c) They store solar energy. No special storage is required.

The above illustrate the attractive nature of wood as an alternate energy resource through an efficient conversio medium. Compared to long time constants of nuclear power plants, their pollution and hazards and operational bugs, these plants based on energy forests might provide an alternative. To answer the question, the following are to be examined:

a) Potential of forests - Is there enough energy without depleting our resources?

b) Cost of benefits - Is it economical?

We discuss below the characteristics of wood, its utilization technologies, forest area available, fast growing species, energy that can be tapped, technological problems and costs.

2. Characteristics of wood

Even now, maximum amount of solar energy uses is that obtained through photo synthesis - mostly for food and fuel (agricultural and forest resources). Forest resources are wood(primary), producer gas, charcoal, methanol etc. (from the point of view of energy only). Many other byproducts got from forests are oils, resins, acids, alcohol, esters, tar. Currently forests provide more than 60 of the fuel requirements of India.

The consumption of wood is growing at the rate of 1 per annum. To bring to the focus the energy potential

available in forests - under the existing growth conditions - we present in Table 1 utilization of hydel and wood resources. The table shows that whereas we will use hydel resources upto 50 , not even 10 of the forest energy potential will be used. Another important factor is the inefficient combustion of wood being used now.

Let us now look at the important fuel characteristic of wood - its heat content and comparison with some common fuels. Table 2 contains the calorific value of some of these fuels and from it, we can infer that common coal used in India has a heat value of only about 1.2 times that of wood. If we consider a net heat value for coal taking into account large energy expenditure for transporting coal over long distances, then the heat value of wood may be more. This justification is similar to the one that made it possible to input lignite into power plants in Neyveli.

Wood is primarily composed of cellulose and lignocellulose together with gums, resins, inorganic matter and a variable amount of moisture. The approximate proportions of the main constituents are: Carbon - 50 , Hydrogen 6 , Oxygen 44 (plus a trace of nitrogen).

The next important factor in the use of wood is its moisture content. Fresh wood might have more than 50 of moisture. This reduces the heating value because of the additional heat required for the evaporation of the water.

The variations in calorific value is provided in table 3.

Specific gravity of wood(air dry) varies from .4-.7, the coniferous variety being denser. The ash content is usually low.

TABLE 1: SOME OF THE RENEWABLE ENERGY RESOURCES OF THE WORLD

	(mtce) Hydro	Geo Thermal	Tidal	Wood and charcoal
Max. possible energy available	1500	3	35	7584
Present growth rate	5.5	-	-	1
Estimated consumption in 2000AD at present growth rates	750			656

TABLE 2: APPROXIMATE CALORIFIC VALUES OF SOME FUELS

Fuel	kcals/kg
Paraffin	10,400
Fuel oil	9,800
Charcoal	7,100
Coal(bituminous)	6,900
Coal	6,640
Coal(average Indian)	5,000
Wood, oven dry	4,700
Wood, air dry	3,500
Peat, air dry	4,000
Dung, air dry	4,000

Wood, when burnt in traditional choolas has an efficiency of less than 10 . Smokeless choolas can increase efficiency to 20 or more. Power plants have efficiencies of about 35 .

Currently wood is used, in addition to cooking, to provide heat in many industries like brickmaking, distilleries, hand made paper works, jaggery production, potteries, tea and tile works, tobacco barns etc. It is also used to produce steam in saw mills.

Some of the woods and their properties are given in table 4. Table 5 provides estimates of wastes from mills. Another characteristic, one should look for in fuel woods is the life cycle of forests containing species which should grow fast and have life cycles of 4-8 years. Hybrid po lars grow fast on branches which are cut regularly. The next section sums up some of these characteristics.

TABLE 3: CALORIFIC VALUE Vs PERCENT MOISTURE

Per cent moisture		Calorific Value of kcalsOkg	
Dry	Wet	dry	wet
0	0.0	5000	5000
10	9.1	4500	4500
25	20	4000	4200
50	33.3	3300	4000
100	50	2500	3300
200	66.7	1700	3000

TABLE 4: PROPERTIES OF SOME WOOD

	Moisture Content	Ashes	Heat value kcals/kg	Btu/lb
Soft woods, air dry	30	1.2	2700	4830
Coffee	9.2	2.42	3915	7010
Leucaena (dry)	10.9	1.62	3895	6970
Hevea brasiliensis	11.3	2.44	3890	6960
Leucaena charcoal		1.0	7250	12980

TABLE 5: PERCENT WOOD WASTES

Type	Percent of wastes
Mill wastes	25 - 39
Lumber production	48
Plywood and veneer mills	48 - 57

3. Characteristics of wood that affect its performance

1. Fuel size: Preferable to hog wood to produce uniform size of wood for handling. Sizing is considered very important on the selection of equipment and operation.
2. Ash content: Not a serious problem in India where the ash content in coal is high.

3. Chemical constitutents: Fuels which have low per cent of volatile elements and gums are more difficult to burn.
4. Heating values: Heating values of wood are comparable to those of lignite and ooal.
5. Moisture content: It has a great effect on combustion. If the moisture percentage is 65 or greater, the fuel becomes uneconomical to burn alone and the boiler may need supplementary fuel. Thermal efficiency of the boiler varies inversely as the moisture percentage in wood.

Let us next look at how wood is used in addition to simple/direct burning. That is charcoal and its production.

4. <u>Charcoal</u>

There are many secondary forest resources got from wood, the important one being charcoal. Charcoal is the hard, black remnants after dry distillation of wood produced when the temperature of the burning wood reaches 250-300°C. The carbohydrate and lignin then are separated and released as damp disappears. The process of carbonization consists of four stages:

1. Combustion - temperature changed from ambient to 600°C and then brought down to 100-120°C.
2. Dehydration - temperature 100-120°C

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3. Exothermic - starts at 270°C and rises to 400-600°C. The byproducts in this stage are acetic acid, alcohol, CO_2, CO, hydrogen, methane, methyl alcohol, nitrogen, pitch, tar.

4. Cooling.

The process might result in an yield of 30 charcoal resulting in a loss of 2.6 million kcals. (55) per ton of wood. It can be made from wood, coconut shell and bone, wood residues and similar materials. It has many desirable properties over wood - does not break easily, less weight for the same heat content, can be easily ignited, will continue to emit heat for a long time. Its main uses are as a fuel for cooking especially in urban areas, and as a fuel in industries like cement, ironsmelting, in direct drying. Activated charcoal has a potential for preventing and combating pollution.

Carbonization to manufacture charcoal, can be done in kilns, retorts, continuous kilns or furnaces. Kilns are simpler to use, require minimal capital expenditure and are labour intensive. But by products are lost when kilns are used, yield is uncertain and there is a restriction on the size of input - small chips could not be used.

Retorts are containers in which wood is subjected to heat applied to the external surface of the apparatus until the charge is converted into charcoal. The gas produced can be fractionalised into products like methyl alcohol, acetic

acid and pitch. The process of obtaining these products is called wood distillation. But retorts are capital intensive, need advanced technology and require external energy for at least part of the process.

Both continuous kilns and furnaces are mainly suited to developed countries desirous of labour reduction. They do not retain by products.

The second process to retrieve organic products is wood distillation. Wood is heated in a closed container so arranged that all gases and liquids pass out through a condenser. The condensible gases can be used as an energy source and the condensed gas give useful organic compounds- methyl alcohol, acetic acid, esters, acetone, wood oil, creosote oil, pitch etc. The third process is gassification. The two gases obtained are producer gas and water gas. Typical raw materials for gas production are - wood, refuse, bark, tannery refuse, saw dust, organic wastes like olive refuse, bagasse, cotton seed husk, rice husk, cashewnutshell, ground nut husk, coconut shell, grape seed, coffee grounds etc. There is a plant in operation in Kerala producing an output of 6000 hp. The ash from this producer plant is sold as a fertilizer.

5. Forest Potential

Having seen the characteristics of wood and its uses, let us consider forest potential available in India.

Table 6 shows the forest area in India, around .75 million sq.km. with .456 million sq.km being classified as exploitable. This excludes village woodlots, fallow lands and planting on road sides, tankbunds, and in between agricultural plots. As already seen, the growing stock is estimated to be 1126-2611 million cum. (ie., 901-2089 million tons). This works out to a growing stock of 65-200cum/ha. the average being 35 cum/ha.

Gross annual increment for forests is 33 million cum with upper estimates of 60-70 m.cum. This calculates the rate of annual increment/ha as .36 tons. Growing stock for nonforest area is estimated to be 1150m.cum. with annual increments of 30m. tons(38m.cum.) of wood.

The above figures bring us to the definition of energy plantations. These are forests(i) with fast growing trees with annual increment rates of 5-25 tons/ha/year or more (ii) with a life cycle of 3-10 years - of recycling, (iii) with the harvesting of the trees or parts of them at the end of a specific number of years(life cycle), (iv) with an intense and controlled cultivation with additional inputs like irrigation and fertilizers, (v) with proper and regular maintenance of nurseries.

The estimates of figures for annual increments in the forests of the order of 5-25 tons(or even 100 tons)/ha/year (table 7) can be used to calculate energy potential that

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could be tapped from these resources. The next section explains procedures to calculate area vs energy relationships.

6. Land Requirements for Energy Plantation

There are two routes to calculate the area requirements. One way is to use mean solar insolation and photosynthetic efficiency and the other route is via estimates of wood production/annum. Let us follow both procedures and calculate the area needed for a 1000 MW plant.

TABLE 6: AREA UNDER FOREST IN 1000ha.

Description	1960-61	1969-70
1. From the point of view of exploitation		
a) Exploitable	46,590	45,580
b) Potentially exploitable	10,020	14,760
c) Others	10,270	14,690
	68,960	75,030
2. By ownership		
a) State	65,240	71,170
b) Corporate bodies	2,290	2,480
c) Private	1,430	1,380
	68,960	75,030
3. By types		
a) Coniferous	4,430	2,180
b) Broad leafed	64,530	70,850
(i) Sal	11,350	11,300
(ii) Teak	8,750	7,340
(iii) Misc.	44,430	52,210
Total	68,960	75,030

TABLE 7: ESTIMATES OF DIFFERENT SPECIES OF WOOD

Species	Area Ha	Annual growth	Trunk growth/ha t/ha/yr
Philippines			
Mangrove	232,097	725,723	3.13
Eucalyptus Anthocephalius chinensis Albizia falcataria Gmelina arborea			11.9-21
Leucaena Leucocephala (ipil-ipil)			12-110.8
a. Davao Peruvian			31-66.5
b. Batangas K8			16.3-25.9
c. ,, K28			12.6
d. ,, K67			13.2
e. UPLBK8			110.8
f. UPLB K22			112
g. UPLB K28			149.5
h. UPLB K67			90.3
i. Canlubang K28			25.2
j. ,,			25.8
Eucalyptus			2.5-13
Casuarina			,,

Assumptions:

(i) mean solar insolation is 668 cals/cm^2/day,

(ii) Photosynthetic efficiency is assumed to be .7 ,

(iii) Crop rotation is 8 years. That is, we harvest the trees after 8 years,

(iv) Power plant is supposed to have a capacity of 1000 MW operating at a thermal efficiency of 35 and at a load factor of 60 .

Then, Solar insulation for 8 years = $6.192 \times 365 \times 10^5$ units/ha

fuel value of the crop = $4.3344 \times 365 \times 10^3$ kwh/ha

Fuel value needed to operate the plant

$$= \frac{1000 \times 10^3 . 60 \times 24 \times 365}{.35} \text{ Units}$$

$$= \underline{41.2 \times 365 \times 10^6 \text{ kwh}}$$

$$\text{Area required for operation} = \frac{41.2 \times 10^6}{4.23 \times 10^3} \text{ ha}$$

$$= 9500 \text{ ha.}$$

To support the power plant on a continuous basis, the land requirement is = 76,000ha.

The second method of calculation is to use the yield and compute energy/ha to get the area required. We make the following assumption:

(i) Calorific value of wood = 4670 kcals/kg

(ii) Load factor of the plant = .50

(iii) Thermal efficiency = 35

(iv) Total area needed is the area needed/year multiplied by the growth cycle.

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(v) Yield/year is constant.

(vi) Total yield of a harvested area is yield per year multiplied by growth cycle.

Sample calculation for a casuarina plantation with a yield of 5 tons/ha/yr and a growth cycle of 10 years has been performed and the steps are given below;

Total yield of a harvested area = 50 tons/ha/yr.

Heat value/ha = 233.5×10^6 kcals/yr/ha

= 269×10^3 kwh(th)/yr/ha

= 94150 units(elec)/yr/ha

For a load factor of 0.5, 1 kw generates 4380 units(elec)/yr.

Hence power generated/ha = 94150/4380

= 21.44 kw/ha.

Area needed for a 1000 MW station = $10^6/21.44$

= 46500 ha

Total area = 465,000 ha.

Area to be harvested/day = 127 ha/day.

Nursery area required = 2325 ha.

The area requirements as calculated by this method for different species are given in table 8. Comparisons have been portrayed in table 8a of area calculations done by various persons.

We can see from table 8, a feasibility for power plants of 1000 MW existing. Continguous area search might

Some of the technical aspects of wood burning in boilers and handling of wood are illustrated in the successive sections.

7. <u>Methods of handling and conversion of wood and bark to fuel</u>.

1. <u>Storage</u>: Dead storage means that recovering the material needs human effort-use of forks and shovels-or bull dozers. It is used outside the boiler room. Live storage implies recovery through mechanical ways and may be, without human intervention. It is inside or adjacent to the boiler room.

2. <u>Weighing</u>: It is possible.

3. <u>Drying:</u> Fuel wood especially with large moisture needs drying.

4. <u>Sizing</u>: Use hogger or chipper. Some types of conveyers and fuel combustion systems might take any size of fuel. But others require sizing to certain specifications.

5. <u>Pressing</u>: (Briquets) Bark and wastes from pulp and paper mills and saw mills must be pressed and bonded.

6. Methods of conveyance of wood from source to boiler house.

   a) Pneumatic systems

   b) Drag chains

   c) Belts

   d) Buckets

   e) Bull dozers pay loaders etc.

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8. Methods of burning wood fuels

1. Pile burning: Wood is burnt in the furnace/cells, kept as a conical pile and burns on the periphery. Control is poor Advantages are most of the fuel is burnt and very wet fuels can get dried, ash removal may be difficult. Maintenance needed is high.

TABLE 8: AREA REQUIREMENTS FOR A 1000 MW PLANT (CALCULATED)

Species	Annual yield tons/ha	Growth cycle (yrs)	Power production per ha kw	Energy/ha kwhe	Area needed for a 1000 MW plant (ha)	Nursery (ha)
Eucalyptus	2.5	10	10.72	47,085	9,30,000	465
Casuarina	5	10	21.44	94,150	4,65,000	232.5
Fuelwood	13	30		7,36,000	1,78,500	24.75
Eucalyptus	6.5	8	22.5	98,500	3,56,000	222.5
Eucalyputs	13	8	45	1,97,000	1,78,000	111.3
Fuelwood	1	30			0,500	

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TABLE 8a. ESTIMATES OF PLANTATION AREAS

Source	Area (ha)	Area/MW (ha)
1. Szego and Kemp	95,800	239.5
2. Vergara (13.66 t/ha/yr) (common ipil-ipl)	33,203	442.72
3. Giant ipil-ipil(50t/ha) (Semana et.al.)	9,071	120.95
4. Reddy and Prasad	7.4	175.2
5. D.O. Hall	12,000	30
6. Prasad	3.5	84
7. Prasad and DKS	76,000	76
8. Eucalyptus (13t. DKS)		178
9. Casuarina (5t)		465
10. Eucalyptus (2.5t,DKS)		930
11. Fuelwood(1t, DKS)		2,320

2. Inclined grates: Fuel passes thro' a drying section and goes to bruning sections. Ash flow to the ash section in the bottom. The grates may be water cooled. Fuel size is not very important in this case. Accurate control of incoming fuel is not necessary. Wet fuel can be dried.

3. Spreading Stoker firing onto grates. Fuel is delivered to the stoker at a controlled rate and is delivered by the stoker into the furnance where some of it burns in suspension and therest lands a grate.

Good control is needed as the fuel bed on the grate is thin. Little or no attention is required to fuel sizing. Carry over is more.

Different types of grates that may used are (a) stationary grate, (b) dumping grates, (c) vibrating grates and (d) travelling grates.

4. Suspension burning: The bark fuel is finely hogged, blown into the furnance and burned in suspension along with the main fuel like coal, oil or gas. Maximum bark input in this case is limited to 30 of the total heat input.

9. <u>Availability of wood fired boilers</u>

Forest industry companies in U.S. and Canada generate steam/electricity from wood and bark. One of the leading manufacturers of these boilers in Canada estimates that their boilers consume 636 tons of wood and bank per hour

totally, in Canada alone. This means consumption of 4579 mt of wood/bark annually. There are three other large manufacturers in U.S. and Canada (Combustion Engineering, Babcock and Wiloox and Riley),

The next section gives examples of existing plants.

10. <u>Existing Plants utilizing wood</u>

<u>Eugene, Oregon (USA) Plant</u>.

This is a central steam plant, uses wood as fuel to generate electricity and steam. It consumes about 1,25,000 dry tons of wood and bark annually. There is another unit at the university consuming 75,000 tons of wood/year. The cost of wood waste was $4.58(Rs.36) per ton and cost of steam production was around 12 cents/kg and cost of electricity was about .7 cents/units. There are two wood fired boilers with a total capacity of 164 tons of steam/hour. Steam can be produced upto 42 kg/cm^2 (600 psig) and 446°C. The total electricity generating capacity is 3.2 MW. Load factor is around 64%.

There is a plant generating electricity from wood in Andamans. One of the earliest users of wood for industry is the Mysore Iron and Steel Co. at Bhadravathi, Karnataka State. Now let us look at costs of generation.

11. <u>Costs of wood based power plants</u>.

(1) One estimate of the investment needed for a 25 MW plant is $7.59 million and a 50 MW plant is $14 million.

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Cost of power production is about .45 cents/units to .7 cents for 50 MW plant, and varies between .5 to .75 cents/unit for the 25 MW plant. (Wood costs are assumed to be $4/ton (dry). These costs compare well with the costs of energy tariffs of BPA and other (.18 - .3 cents/unit). Cost of wood becomes $ 31-43/ton after yarding, loading, hauling and hogging or chipping.

(2) A second estimate for wood fored plants and comparison to oil fired plants of size 2.5 MW capacity are given in table 9. Costs/kwh are 3 and 4.8 cents respectively for wood and oil fired plants.

(3) A third estimate again from U.S. for a 45.4 t/hr fuel rate stem power plant is .4 cents/unit of energy. Its annual power output is 70 million units and capital cost is about 1 million dollars.

(4) A fourth estimate is prepared for our 1000 MW plant - discussed in this paper. Assuming cost of wood to be Rs.130/ per ton, the cost per unit of electricity comes to 22.4 paise/ unit.

Conclusions

Wood based power plants - centralized or decentralised direct or with charcoal, forest based or village woodlot based - seems to be a good alternative for various levels of energy generation. The resources are well distributed - without a need for long hauls of transportation. Economics also favours them. Ecology will improve with controlled forestry development Forest revenue will increase.

3,4,2

TABLE 9: TYPICAL COSTS - CAPITAL AND OPERATING FOR A 2.5 MW PLANT IN U.S.A.

	Wood fuel 1000 Rs.		Oil fuel 1000 Rs.	
Turbo generator	6000	50.6	6000	63.7
Boiler and au. units	2400	20.3	140	11.0
Condenser	720	6.1	720	7.6
Fuel handling system	4	13.5	560	5.9
Connection/controls	720	6.1	720	7.6
Substations	400	3.4	400	4.2
Total equipment cost	11840	100	9440	100
Contingencies	1200	10.1	800	8.5
Engineering	720	5.5	560	55
Total capital investment	13,760		10,800	
Average fuel rate	4.54t/hr		5.5bbl	
Annual fuel rate	37,000 tons		45,000bbl	
Annual fuel costs	960		4800	
Annual operating cost	1760		1200	
Annual capital cost	2000		1600	
Annual costs	4720		7600	
Cost/Kwh	24 paise		39 paise	

ANIMAL ENERGY UTILIZATION IN UNGRA - I : FOR PLOUGHING DURING THE PREMONSOON SEASON.

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ANIMAL ENERGY UTILIZATION IN UNGRA - I : FOR PLOUGHING DURING THE PREMONSOON SEASON.

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Productivity in agriculture in India is generally low for all the field crops, especially so in the dry farming regions. A productivity study [1] conducted in Ungra village (in the dry belt of Karnataka) during 1979-80 showed that the average productivity of Rice was 2.3 tonnes/hectare and Ragi (finger millet)was 1.24 tonnes/hectare. It is very important to analyse the factors contributing to the lower productivity.

Productivity in agriculture depends on energy, nutrients, water and the timeliness or the seasonality of the performance of various agricultural operations. Energy, water and the seasonality of agricultural operations are interrelated. The characteristic of Indian agriculture is that both the energy use per hectare and the productivity per hectare are low and the traditional agriculture requires lower inputs of energy compared to the fossil-fuel based modern agriculture [2].

Crop production is a result of functional relationship between the plant (species) and abiotic factors like solar radiation, temperature, water

(rainfall or irrigation) and humidity. This inter-relationship sets a physiological calender of operations for each crop species for higher productivity. Crop production which involves providing energy subsidies requires the performance various operations from land preparation to processing of harvested crop. In the present study we are going to relate the plant physiologic calender with the cropping calender observed in the field, which is a result of the availability of energy and the technology of its use.

Animals provide the basic draft energy for Indian agriculture. This presentation is a part of the project on 'Energy in Ungra Agriculture' currently going on at the village centre of ASTRA. The main objective at this stage of the study is to look into the animal energy use for the ploughing operation and its impact on cropping pattern and productivity. The specific objectives are,

(i) to estimate the power requirement for ploughing under different moisture regeims,

(ii) to study the animal power availability and its utilization for ploughing,

(iii) to compare the optimum sowing periods with the periods observed in the field,

(iv) to understand the impact of draught animal energy use on cropping pattern and its productivity

METHODOLOGY:

The present study is a part of the ASTRA'S village studies in ungra. This is a continuation of the two earlier studies: (i) Energy consumption patterns, and (ii) An Indian village agricultural ecosystem. The methodology for the present study has evolved from the previous two studies and through intensive discussions with the villagers.

Ungra village was selected for the study. The whole village ecosystem is considered for the study, which is a Land-livestock-human ecosystem.
The main approaches of the study are:

(i) Monitoring of all agricultural operations by actually observing in the field every day in each farmer's plot for one agricultural year. This was achieved with the help of the local boys.

(ii) Survey of the land use pattern in all the three seasons of the year.

(iii) Estimation of the productivity of crops.

(iv) Estimating the power requirement for various agricultural operations.

(v) Recording of climatic factors like, rainfall, solar radiation.

(vi) Recording of some of the agronomic factors like fertilizer inputs, seedling density.

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Ungra falls in the dry tract of Karnataka with an annual rainfall under 75 cms. (normal rainfall of 68 cms). Ungra village has 149 households with a population of 932. The area of the village is 360 hectares with a total cultivable area of 286 hectares. The main source of irrigation is the seepage water from the upstream tanks of Shimsha river. In Ungra three cropping seasons are practiced.

(i) Premonsoon season - early April to end of June.
(ii) Kharif - July to end of November.
(iii) Summer - January to April.

Ungra falls in the Kharif dominated region. Kharif is the main cropping season. All the three seasons are being studied. The analysis is in progress at different stages. Here only the preliminary results of the premonsoon season are presented.

PREMONSOON SEASON (PMS)

Premonsoon season begins with the first rains normally in the last week of March or early April. PMS accounts for about 30 per cent of the annual rainfall (Table 1). Farmers in this region utilize the PMS rainfall for preparing the land for kharif paddy and in the process take one pulse crop or a cereal crop. The pulse crops taken in ungra during PMS require only

three operations, namely, ploughing, sowing and harvesting in that order. Ploughing is the most crucial operation. During the PMS of 1980-81 the first rains were received in the last week of March (16 mm). The ploughing operation started immediately. May received the maximum rainfall (112 mm) of the season.

OBJECTIVES OF PLOUGHING OR TILLAGE:

Tillage of soil consists of breaking up the hard compact soil surface to a certain depth and converting it to a loose powdery mass. The objectives are: (i) to remove weeds, roots, stubble, weedseeds and other sprouting material to produce a clean soil medium, in order to eliminate competition between weeds and crop plants for solar radiation, nutrients and water, (ii) to increase moisture intake into soil. On a hard unbroken surface rainwater merely flows off and is lost to the soil. With every ploughing the soil lumps are made smaller and smaller and the rainfall penetrates into the soil more easily and the surface area of the soil particle is largely increased,
(iii) to improve air circulation in the root zone and to create favourable condition for the microbial activity and (iv) to destroy insect pests.

Farmers in Ungra normally give 2 ploughing for the PMS crop. First ploughing is given with an iron plough and second ploughing using a wooden plough.

SOURCES OF ENERGY FOR PLOUGHING:

The source of energy for ploughing comes from animals. In ungra cows as well as bullocks are used for ploughing.

POWER REQUIREMENT FOR PLOUGHING:

Ploughing experiments were conducted at the Ungra extension centre. Bullocks were used to plough in the red sandy loam soils with a mould board iron plough. Force, velocity, depth of ploughing and soil moisture observations were recorded and horse power (HP) used for ploughing was estimated for the first ploughing. The HP required at different moisture levels during the first rains is given in Figure 1.

Figure 1 shows that when the moisture level was at the highest level after the rainfall at 15.6 percent the HP required was 0.521. As moisture level decreased the HP required also initially decreased and was lowest when the moisture level was 11.50 per cent. The HP required started increasing as the moisture level further decreased. At 11.23 per cent moisture level the HP

required was highest and it was difficult to plough at this moisture level. It was not possible to plough beyond this level.

The crucial factor in the HP required and moisture level is the number of days upto which the ploughing can be performed (ploughing window) using draught animals. Figure 2 indicates the ploughing periods as observed in ungra during PMS. In the experiment conducted for the first rains of the season it was possible to plough upto 6 days. The field observation also showed that in the first ploughing peak,ploughing was carried out in Ungra for 6 days. This shows that if all the land has to be sown during the first rain, all the land has to be ploughed in 6 days.

OPTIMUM SOWING PERIODS:

Considering the normal rainfall trend for the PMS the ideal sowing periods for different pulse crops are given in Figure 3. The ideal time for sowing horsegram, blackgram, greengram, cowpea is the first week of April i.e., during the first rain of the season. The next ideal time is during the second rain or during the last week of April. The sowing has to be completed with in the April so that the plants come to

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flowering in May, as the rainfall in May is maximum and assured. Flowering and pod formation are the critical periods for all the pulses. If the sowing is taken up in mid-May or in second half of May there may not be moisture in the soil for the plants, and the productivity will be considerably reduced.

It is to be seen to what extent the farmers were able to stick to the optimum sowing dates in Ungra and to what extent the ploughing influenced the sowing pattern.

RAINFALL AND PLOUGHING WINDOW:

The length of the ploughing periods depends on the preceeding rainfall. Three initial ploughing peaks could be noticed from Figure 2. The first two peaks are in April and the third peak is during the First week of May. In April ploughing, the ploughing range lasted 10 days. During the first week, as can be seen from Table 2, 25 per cent of the land was given first ploughing. In April less than 50 per cent of the land was given first ploughing. It can also be noticed that the first ploughing was given in Ungra upto the middle of June.

When the total ploughing is considered only 30 per cent of the land was covered during April.

This clearly shows that the ploughing was staggered beyond April and even upto the end of June. Next it is to be seen, what was the resulting land utilization pattern.

LAND UTILIZATION PATTERN AND PLOUGHING:

Land utilization pattern in Ungra during the PMS is given in Table 3. In Ungra only 56 per cent of the total cultivable land was cropped. Out of the total cropped land 70 per cent of the land was under horsegram and horsegram-pulses mixture. Horsegram is a legume and fixes nitrogen in the soil. Horsegram is a drought resistant crop of 90 days duration. Horsegram can be ploughed into the soil at any time.

In April 30 per cent of the land was ploughed and correspondingly 40 per cent of the total area under horsegram was sown. In May 50 per cent of the horsegram land was sown correspondingly 46 per cent of ploughing was given during May. The correlation coefficient between horsegram area sown and DAP hours used for ploughing was 0.86. This only further confirms the higher degree of association between the two factors. Two points emerge from the analysis.

(a) Nearly half the land remained fallow during the PMS resulting in the loss of biomass productivity to that extent.

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(b) Even the area sown under horsegram was not completely sown in the optimum period. Over 50 per cent of the land was sown in May which is not the most ideal sowing time.

BIOMASS PRODUCTIVITY:

Biomass productivity of the major crops grown is given in Table 4. Horsegram samples were taken from April sown plots and May sown plots separately. The above ground biomass of horsegram sown in April was 295 grams of dry matter/m^2 compared to 95 grams of dry matter/m^2 for the May sown horsegram.

Ground nut, again a legume, also has yielded a considerable biomass of 1010 kgs/hectare of pods and 1935 kgs shoot part/hectare. It can be seen that all the area under groundnut was sown in April (Table 5). The following points emerge from this.

(a) The village ecosystem has lost biomass from 44 per cent of the land due to the delayed ploughing.

(b) The ecosystem has also last biomass due to the delayed sowing of horse gram.

(c) Farmers were forced to go in for horsegram instead of other more productive crops like groundnut, sesamum and other pulses like cow pea.

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The next question is with the animal energy available is it possible to plough the land in the optimum period. What are alternatives in case all the ploughing has to be completed in April only or during the first two rains.

Draught Animal Energy Requirement:

The question to be answered is what are the factors influencing the DAP requirement that will facilitate the sowing in PMS at the right time. The factors which, on observation, seem to determine the DAP requirement for the ungra ecosystem are:

(1) Total area cultivated by a farmer or the total area in the ecosystem (i.e. area to be ploughed (A_p).

(2) Ploughing window or length of the ploughing range (P_w).

(3) The crop for which the land has to be prepared and the resulting DAP hours required to plough one hectare (N_H).

(4) Number of hours of ploughing per day (N_{HD}).

In Ungra the N_H required is same for all the pulses i.e. 60 hours/hectare. The following expression can be written for estimating the DAP requirement.

$$\text{DAP required} = A_p \left(\frac{1}{P_W \times N_{HD}} \right) N_{NH} \qquad 3.4.6$$

The ploughing window (P_W) lasted for 29 days in Ungra during the PMS. The area to be ploughed (A_p) is 286 hectares. Number of DAP hours (N_H) required to plough one hectare is 60 hours. Assuming an average working day of 6 hours the DAP required was calculated.

The estimated number of DAPs is 99 compared to the observed value of 106 (which is just 7 per cent lower).

If according to the physiological calender if the ploughing has to be completed in April to facilitate the sowing of ground nut, sesamum, horsegram and other pulses, the number of DAPs required is shown in Table 6. In the case of marginal farmers the additional DAP required is marginal. In the case of small farmers the DAPs will have to be nearly doubled. It is only in the case of medium and large farmers the additional draught animals required is very large.

This analysis clearly shows that it is the medium and large farmers who are acutely in short of draught animals compared to small and marginal farmers. A further analysis shows that only the DAPs belonging to small and marginal farming groups are available for hiring in the village. Farmers belonging to all the groups compete for the DAPs available for hiring

on small and marginal farms.

This analysis suggests that with 106 DAPs and the inequitable land distribution it is not possible to plough the land in April. A preliminary analysis of animal energy utilization for ploughing operation during the PMS in Ungra and its relationship with cropping pattern and productivity was carried out and the results are as follows:

The ploughing experiment analysis showed that the crucial factor in the moisture and HP relationship is the number of days upto which the ploughing can be carried out or the length of the ploughing window. The area covered by ploughing in Ungra is determined by the length of the ploughing window during April, which in turn depends on the soil moisture and draft power. With the available animal energy and the technology of its use, ploughing operation in Ungra was carried out beyond the optimum periods. The delayed ploughing resulted in lower cropped area (56 per cent) and the horsegram sowing was delayed and carried into May even though the ideal time for sowing pulses in Ungra is April or during the first two rains. Thus the ecosystem has lost biomass to that extent. Further analysis showed that if the land has to be ploughed within April it is not possible with the available

draught animal power and the technology of its use. No attempt is made to suggest any alternatives as the study is still in progress.

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Table - 1 : Rainfall in Ungra

Month	Rainfall in 1980	Normal Rainfall
January	-	3.6
February	-	4.9
March	16.6	6.5
April	62.7	31.0
May	112.4	91.7
June	53.0	59.9
July	26.8	67.5
August	8.0	93.2
September	193.0	126.0
October	90.0	134.0
November	55.0	61.0
December	11.0	8.5
Total :	628.5	687.9

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Table - 2 : DAP hours used for ploughing and horsegram area sown during the premonsoon season.

Weeks	DAP hours for first ploughing	DAP hours for total ploughing	Percentage Horsegram area sown	Horsegram area sown in hectares	% of la given total ploughi
April I	1680	1824	3.62	3.25	12.23
II	88	130	-	-	0.80
III	-	-	0.18	0.16	-
IV	11121	2565	36.75	33.05	17.20
May I	814	3097	41.62	37.45	20.77
II	517	1509	10.62	9.55	10.12
III	110	1344	1.75	1.57	9.01
IV	624	928	0.87	0.78	6.22
June I	430	1478	2.12	1.90	9.91
II	52	1285	2.43	2.18	8.60
III	-	408	-	-	2.73
IV	-	340	-	-	2.05

3.4.6

Table - 3 : Land utilization pattern PMS of 1980.

Categories	Area in hectares
Total cultivable land	286.76
Total land cropped during PMS	160.82
Percentage of area cropped	56.00
Area left fallow	125.94
Horsegram	111.15
Ground nut	5.68
Ragi	3.99
Sesamum	3.09
Pulses	2.90
Sugarcane	8.86
Others	25.15

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Table - 4 : Plant productivity during PMS of 1980 in Ungra.

Sl. No.	Crop	Productivity per m^2 (in gms)	Productivity (Kgs per hectare)
1.	Horsegram (April sown)	294.99	2949.9
2.	Horsegram (May sown)	94.88	948.8
3.	Ground nut		
	Pods	101.6	1016.0
	Shoot	193.5	1935.0
4.	Sesamum		
	Sticks	211.7	2117.0
	leaves + Pods	76.3	763.0
	Seeds	55.2	552.0
5.	Jowar	990.0	9900.0

3.4.6

Table - 5 : Sowing of Ground nut under rainfed condition.

Date	Area under ground nut (in hectares)
1.4.1980	0.3944
2.4.1980	0.2500
11.4.1980	0.1850
25.4.1980	0.9904
26.4.1980	0.3417
27.4.1980	0.4400
29.4.1980	0.1835
Total area :	2.7650

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Table - 6 : Animal energy availability and requirement

	Average size of holding	DAP available	DAP/farmer availability	DAP required for ploughing in 10 day	Percentage additional power reqd.	percentage DAPs available for hiring
MF	0.57	17	0.38	0.60	5.88	94
SF	1.44	28	0.84	1.44	89	78
MD	3.45	44	1.23	3.45	175	20
LF	12.63	17	2.12	12.63	447	6

3.4.6

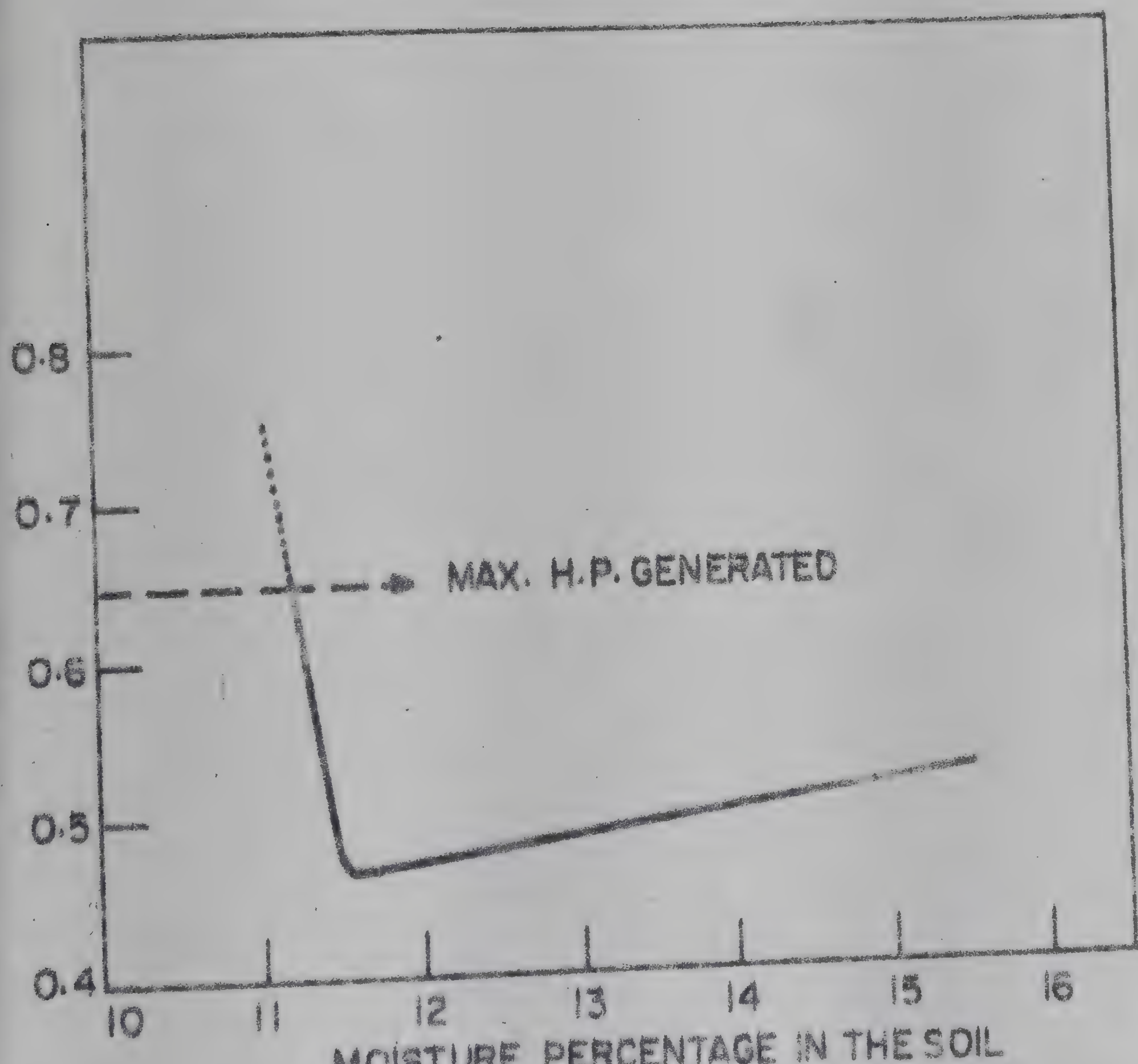

FIG. 1. H.P. REQUIRED FOR PLOUGHING RED LOAM SOILS AT DIFFERENT MOISTURE LEVELS.

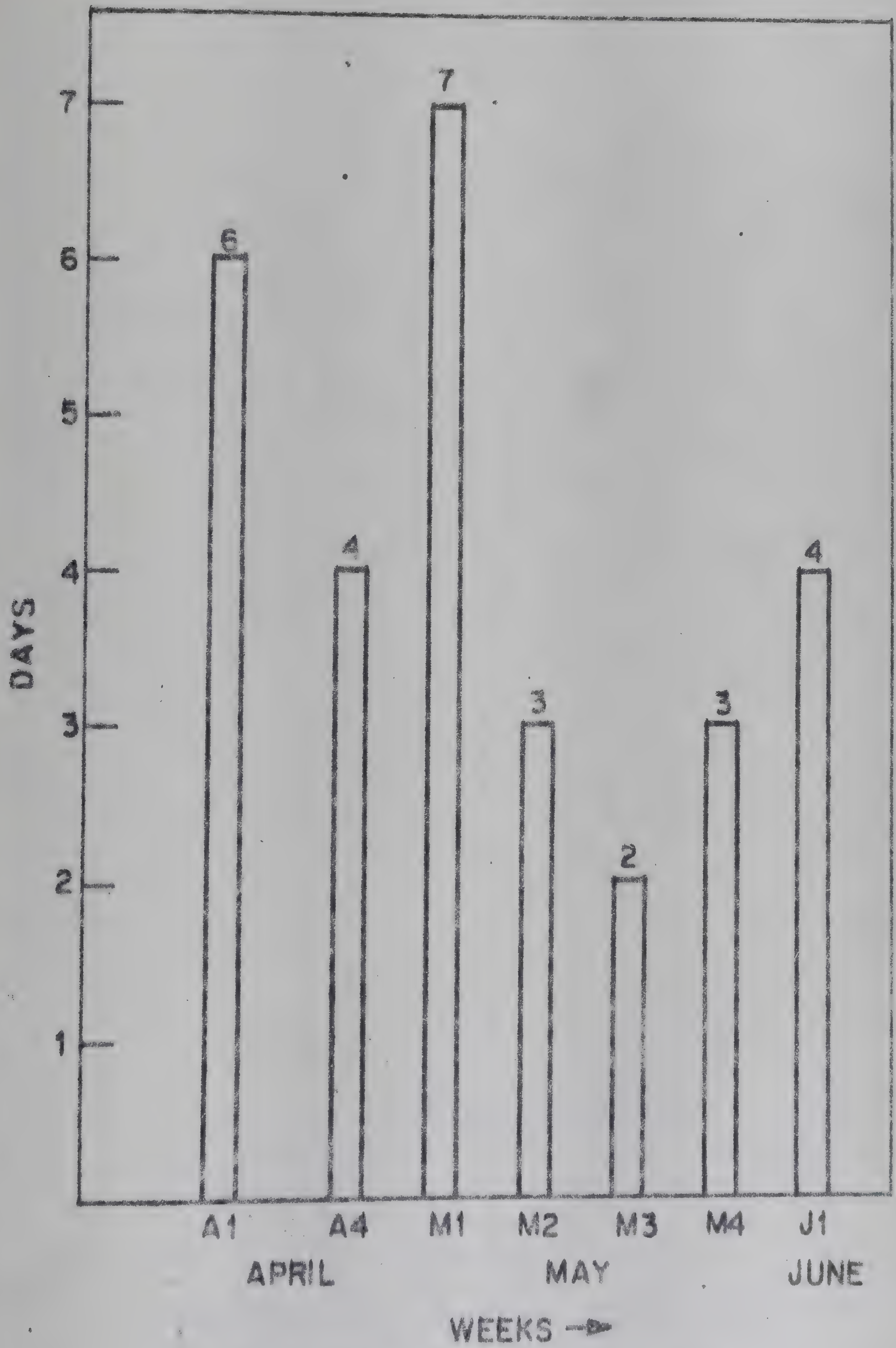

FIG. 2. PLOUGHING WINDOW (WEEKLY)

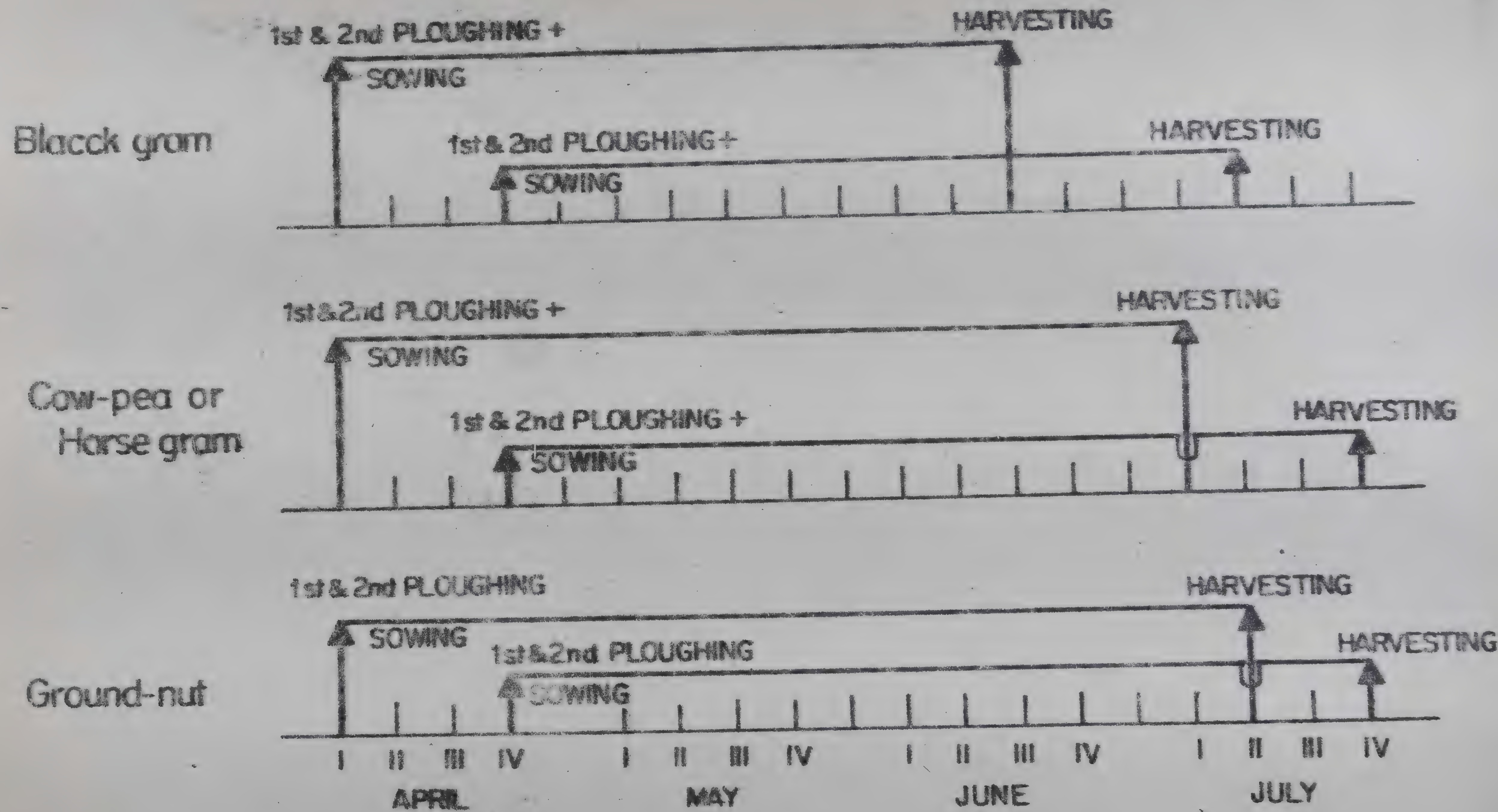

FIG. 3. PLANTING AND HARVESTING SCHEDULE FOR PULSES

ANIMAL ENERGY UTILIZATION IN UNGRA - II: FOR AGRICULTURE AND OTHER ACTIVITIES

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ANIMAL ENERGY UTILIZATION IN UNGRA - II: FOR AGRICULTURE AND OTHER ACTIVITIES

INTRODUCTION

Animals provide the draft power for agriculture and some industries in Ungra. With the advent of diesel, electricity and modernization, animal power is slowly getting replaced by the inanimate sources of energy. It is important in this context to study the animal energy utilization for various agricultural and non-agricultural activities in villages. The objectives of the present analysis are: (i) to estimate draught animal energy availability or supply in Ungra, (ii) to study the extent of animal energy utilization in Ungra in the first six months of the agricultural year, and (iii) to which operations the animal energy is used and to understand the competition for animal energy between different operations or the scheduling of operations.

METHODOLOGY

Ungra village was selected for the present study. The whole village ecosystem (Land - livestock - human ecosystem) was considered for the study. Ungra falls in the dry belt of Karnataka with an annual normal rainfall of 68 cms. The main source of irrigation water is the waste water from the tank across the Shimsha river. Ungra has 149 households with a population of 932, with a total cultivable area of 286 hectares.

In this paper only the premonsoon season and the kharif land preparation periods of the agricultural year 1980-81 are considered. At the end of the agricultural year data for one full year will be available for a more meaningful analysis. At this stage only the preliminary results are presented.

DRAUGHT ANIMAL PAIR (DAP) AVAILABILITY IN UNGRA:

There are 106 DAPs in Ungra (Table 1). In Ungra bullocks as well as cows are used for draft purpose. The per hectare

DAP availability in Ungra is 0.369. A look at the holding wise analysis shows that DAP/hectare is higher on small and marginal farms compared to medium and large farms. In Ungra 64 percent of marginal farmers (less than 1 hectare) and 27 percent of small farmers (1 to 2 hectares) do not own DAPs. On the other hand all the medium and large farmers owned DAPs. The households not owning DAPs have to totally depend on hired labour. A further look at the Tabl also shows that all the farmers in Ungra depend on surplus DAP hours from DAP owning small and marginal farmers. Even most of the medium farmers owned cattle they accounted for 40 percent of the DAP hour hired during premonsoon season. the Part I it is shown that if the ploughing has to be completed in the specific period (in April) it was large an medium farmers who need large additional animal energy for ploughing compared to small and marginal farmers.

ANIMAL ENERGY UTILIZATION

Activities for which animal energy is utilized is give in Table 2. In agriculture animal energy is used for land preparation, interculture, threshing, transportation and wa lifting. Animal energy is also used for various agro-based industries and house construction activity.

Animals in Ungra are employed for 6 days in a week and every Monday is a rest day. The weekly animal power availa bility, assuming that all the animals are available, is abo 3800 DAP hours. Weekly animal energy utilization is given in Table 3 and Figure 1.

For the period under consideration two peaks can be observed. The first peak is during the fourth week of Apri and first week of May and the second peak is during the fir and second week of August. During the first peak 68 DAPs were used per day and during the second peak 108 DAPs per d were used as against the availability of 106 DAPs in Ungra.

During the second peak, probably, the DAPs were imported from outside the village. Out of the 24 weeks the animal energy capacity utilization was nearly 50 percent or above, only for 7 weeks. The animal energy utilization was less than 10 percent of the capacity available for 7 weeks out of the 24 weeks (that is 30 percent of the period). The animal energy utilization over the period of 6 months was only 28.5 percent of the availability.

This clearly indicates that only during the two peaks animal energy utilization was close to the capacity available. During the other period the animals were underutilized. The 6 months under consideration are crucial months for animal energy use in agriculture.

ENERGY FOR MAINTENANCE OF ANIMALS

An earlier study in Ungra (1) showed that animal energy input to agriculture accounts for 53 percent of the total energy input. The same study also revealed that 617 tonnes of plant biomass (of which 448 tonnes came from crops) was consumed by the draught animals of Ungra during the year. In energy units 2121 million kcals go into the maintenance of draught animals as can be seen from Table 4. In the first 6 months of the year 32580 DAP hours were used in Ungra (Table 3). Assuming that half the fodder ration was given during the 6 months period, the total fodder consumption by the draught animals amounted to 1060 million kcals. The total draught animal energy output during this period was 75 million kcals. This results in 7 percent efficiency for the draught animals.

The draught animals utilization from both the considerations was very low. This is important because the fodder requirement of animals influenced the land utilization pattern (2) in Ungra. In Ungra one-third of the cultivable land is under pasture used mainly for grazing. In Ungra

69 per cent of the total cultivated land under cereals and 3 per cent of the total cultivated land under pulses was going-in for maintenance of animals in addition to providi grains. One of the considerations to go in for local vari of paddy, though the grain yields are lower, was to meet t livestock fodder requirement.

The following points emerge from the analysis for consideration:

(i) On the one hand, as seen in earlier part, the anima power available is not adequate for completing ploughing i April, on the other hand, this part shows that the animal energy utilization was low.

(ii) Any decision on the size of the draught animal popula is going to have its impact on cropping pattern and the vice-versa is also true.

OPERATIONS PERFORMED

What are operations performed during the peak and lea periods, is the next question. It can be observed from Table 5 that ploughing accounted for 77 percent. Harrowi and transportation accounted for 13 percent and 8 percent the total DAP hours respectively. These three operations accounted for 98 percent of the total animal energy utiliz in Ungra.

During the first peak 90 percent of the DAP hours use was for ploughing and in the second peak 68 percent of the DAP hours used was for ploughing.

<u>Ploughing:</u> Ploughing is the most crucial operation for wh draught animals are used. Even a discussion with the farm also reveals that ploughing is the main consideration in g for draught animals. Figure 1 shows that the first peak corresponds to horsegram sowing and the second peak corres to paddy transplanting.

As seen in Part I, the horsegram sowing was delayed due to the delay in ploughing. Adding to this nearly half the land remained fallow due to the delayed ploughing. Similarly July is the best month for transplanting paddy, the next best period is the first fortnight of August. In Ungra major part of the transplanting was carried out in the second fortnight of August. Shortage of DAP was one of the reasons for the staggered planting. In Part I it is shown that biomass productivity was affected considerably due to the delayed ploughing. This Part and the Part I have given indications of the importance of timely ploughing in determing cropping pattern and productivity.

Harrowing: The objective of harrowing is to break down the small clods left unbroken to produce fine filth in the soil. Harrows are used in paddy fields to produce puddle conditions to obtain levelling of the soil for holding water uniformly all over the plot. Harrowing accounted for 13 per cent of DAP hours used. On an average 30 DAP hours are required per hectare for harrowing as against 66 DAP hours per hectare for ploughing.

Harrowing operation follows ploughing operation. Thus the ploughing operation is crucial to harrowing also.

Transportation: In Ungra during the period under consideration DAPs were used for transporting mainly manure and soil for crop fields, and for transporting house construction materials. The maximum number of DAPs used for transporting in any week was 49. Transportation was carried out in 18 weeks out of the 24 weeks. There are only 6 weeks out of the 24 weeks when more than 5 DAPs were employed. The load transported during the 6 months assuming 400 kgs per cart load (largely manure or soil), for 380 days of transporting and 6 trips per day would be 912 tonnes for the 6 months period. That means only 5 tonnes a day. The load carried is very low. The load carried and the DAP hours used are very low to make

any considerable impact on decisions relating to animal en
as compared to ploughing.

Clash of operations: A comparison of transportation and ploughing (Figure 1 and Figure 2) shows that there is no clash between these two operations. The three peak of transportation are: (i) second week of April, (2) second a third week of May, and (iii) fourth week of June. These a the lean periods for ploughing. These two operations are spaced in such a way that they do not clash. Obviously farmers give preference to ploughing to other operations, ploughing is very seasonal.

Here animal energy utilization for various activities analyzed with an objective of understanding the extent of animal energy utilization and the scheduling of important operations. The preliminary results of the study conducte in Ungra are as follows:

The per hectare availability of animal energy was hig for smaller farms compared to medium and large farms. But the number of farmers not owning draught animals was highe for smaller farms compared to larger farms. Even the surp for hiring largely comes from small and marginal farms.

Animal energy utilization is concentrated in two peak The first peak corresponds to ploughing for horsegram sowi and the second peak for ploughing and harrowing for paddy transplantation. The available animal energy utilization nearly total only during these two peaks. The overall uti tion was very low (28.5 percent). The draught animals use their feed with an efficiency of only 7 percent. On the o hand animal energy availability was inadequate to complete the ploughing in the desired time, and on the other the utilization of available animal energy is very low, except the two peak periods. So any strategy for animal energy utilization will have to consider the above fact in

addition to the understanding obtained in earlier Ungra studies that the animal energy utilization determines the cropping pattern and productivity and at the same time the impact on land utilization pattern in determining the population of the draught animals. This study also stresses the fact that ploughing is the most crucial operation.

References

1. Ravindranath N H *et al* (1980) "An Indian Village Agricultural Ecosystem - Case Study of Ungra Village Part I" (draft paper).

2. Amulya Kumar N. Reddy (1980) "An Indian Village Agricultural Ecosystem - Case Study of Ungra Village Part II" (Draft paper).

Table 1 : Animal Energy availability in Ungra

Class	Average size of holding (hectare)	Total No. of far-mers	No. of HH with DAP	Total No. of DAPs	DAP/ hect.	% of DAP avai-lable for hiring	Hired in DAP
MF.	0.57	34	15	17	0.88	94	54
SF.	1.44	38	28	28	0.51	78	92
Md.F.	3.45	38	35	44	0.33	20	134
L.F.	12.63	8	8	17	0.16	6	52
Total		118	86	106			

Table 2 : Activities for which Animal Energy is used in Ungra

AGRICULTURE	INDUSTRY
1. LAND PREPARATION Ploughing Harrowing Puddling	1. OIL CRUSHING 2. JAGGERY MAKING 3. BRICK KILN (Transportation of wood) 4. TRANSPORTATION OF HOUSE CONSTRUCTION MATERIALS
2. TRANSPORATION	
3. SOWING	
4. HOEING	
5. THREASHING	
6. ROLLING	
7. WATER LIFTING	

Table 3 : DAP USE IN UNGRA ECOSYSTEM

Month and Week	Ploughing		Other Agri-cultural operations		Agricul-tural transport		Non-agricul-tural transport		Transport Total		TOTAL	
	No.	Hrs.	No.	Hrs.	No.	Hrs	No.	Hrs.	No.	Hrs.	No.	Hrs.
APRIL-I	307	1824.00	2	10.00	2	16.00	-	-	2	16.00	311	1850.00
II	23	130.00	-	-	37	238.00	-	-	37	238.00	60	368.00
III	-	-	-	-	12	80.00	1	8.00	13	88.00	13	88.00
IV	346	2564.77	5	27.08	25	140.00	3	18.00	28	158.00	379	2749.85
MAY - I	435	3097.79	5	31.25	1	4.84	2	11.16	3	16.00	443	3145.04
II	254	1509.29	4	19.00	9	60.99	40	225.33	49	286.32	307	1814.61
III	227	1344.27	6	30.91	7	35.77	39	280.48	46	316.25	279	1691.43
IV	179	928.66	2	10.83	16	123.38	9	56.91	25	180.29	206	1119.78
JUNE- I	273	1478.63	3	20.82	3	12.25	-	-	3	12.25	279	1511.70
II	261	1285.13	9	57.65	11	62.04	-	-	11	62.04	281	1404.82
III	88	408.08	12	69.59	31	180.57	-	-	31	180.57	131	658.24
IV	73	345.03	14	82.40	36	247.53	7	51.61	43	299.14	130	726.57
JULY- I	32	134.60	15	71.00	31	189.64	1	7.00	32	196.64	79	402.24
II	19	67.63	5	10.83	25	164.23	-	-	25	164.23	49	242.69
III	108	539.97	14	75.89	16	91.06	-	-	16	91.06	138	706.92
IV	222	1315.60	35	169.53	12	68.73	-	-	12	68.73	269	1553.86

(contd.......)

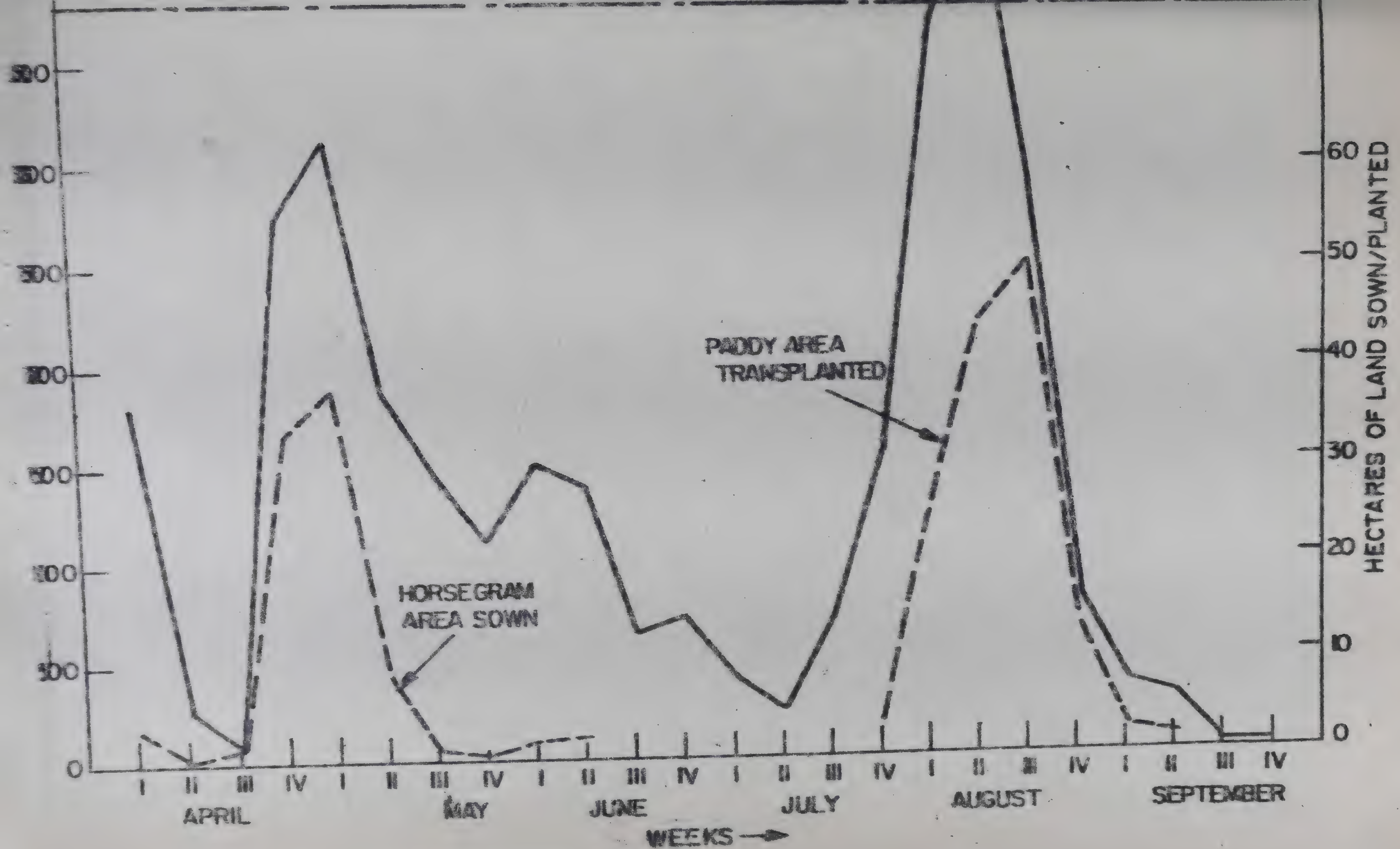
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13
AUG - I	456	2929.99	129	774.07	2	9.66	-	-	2	9.66	587	3713.72
II	479	3139.94	233	1311.11	2	12.00	-	-	2	12.00	714	4463.05
III	210	1396.42	260	1429.93	-	-	-	-	-	-	470	2826.35
IV	59	407.89	77	418.60	-	-	-	-	-	-	136	826.49
SEP - I	25	157.99	32	193.04	-	-	-	-	-	-	57	351.03
II	25	203.06	21	110.51	-	-	-	-	-	-	46	313.57
III	2	16.72	1	6.16	-	-	-	-	-	-	3	22.88
IV	2	9.84	4	19.52	-	-	-	-	-	-	6	29.66
	4105	25235.30	888	4950.02	278	1736.69	102	658.49	2395.18		5373	32580.50

Table 5 : DAP Use for various operations

	Total DAP hours for 6 months	% to the total DAP hours for all operations
Ploughing	25235	77.45
Harrowing	4335	13.30
Transportation	2395	7.35
Other agricultural	615	1.88
Total:	32580	99.88

Table 4 : Fodder Consumption in Ungra
(Bullocks and Cows)

Sl. No.	Type of Fodder	Qnty. in tonnes	Quantity in kcals
1.	Paddy straw	387	1481.8×10^6
2.	Sorghum grains	1	3×10^6
3.	Sorghum straw	43	175.69×10^6
4.	Fallow+Marshy+Grass land	169	460.93×10^6
	Total	600	2121.42×10^6
For 6 months		300	1060.7×10^6
Kcals of DAP used in six months		-	74.93×10^6



HECTARES OF LAND SOWN/PLANTED
0
10
20
30
40
50
60
PADDY AREA
TRANSPLANTED
HORSEGRAM
AREA SOWN
I II III IV I II III IV I II III IV I II III IV I II III IV I II III IV
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
WEEKS

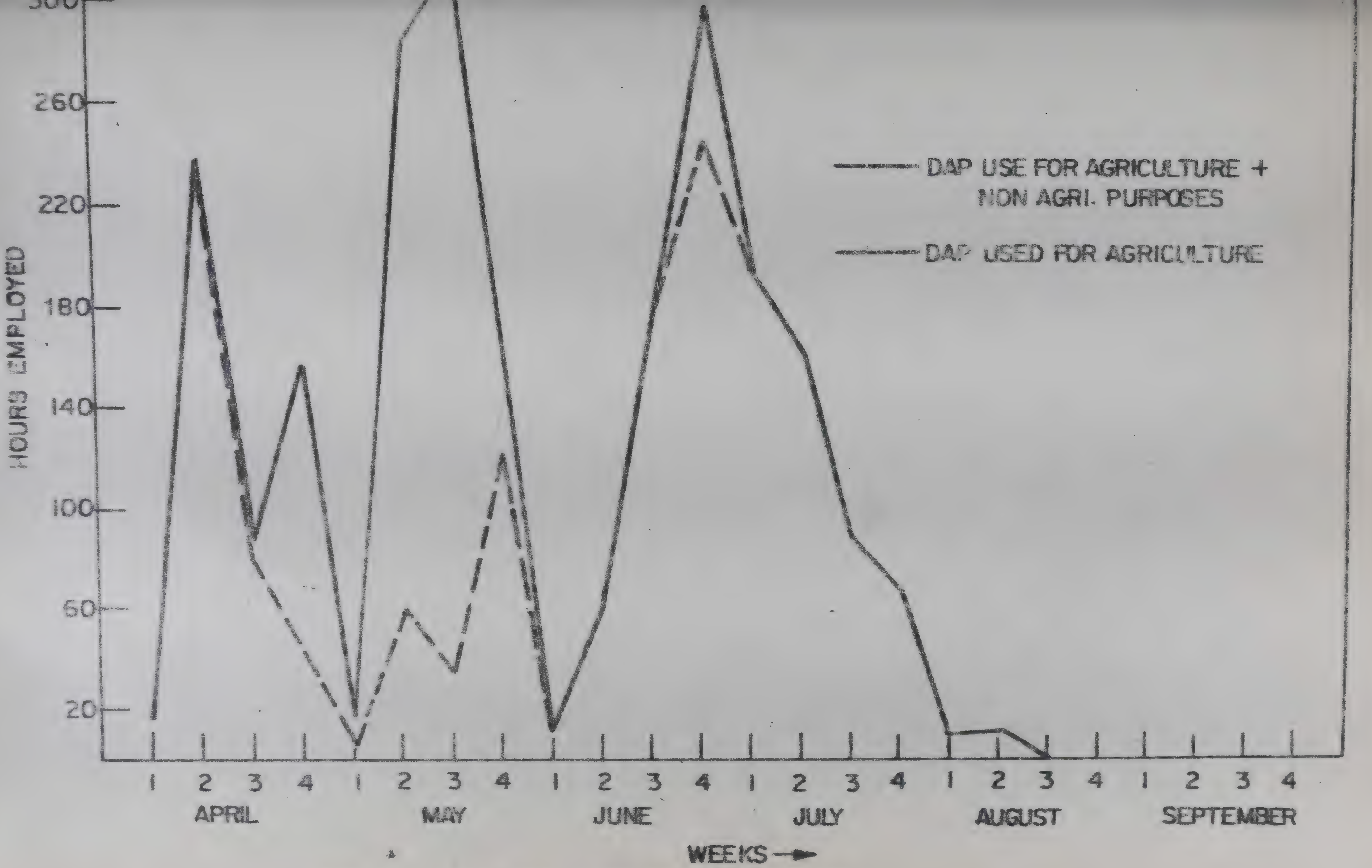


FIG. 2. DAP USE FOR TRANSPORTATION

INVESTIGATIONS ON UTILIZATION OF SISAL LEAVES

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Lecture 4.1 f
Rural Technology Course.

INVESTIGATIONS ON UTILIZATION OF SISAL LEAVES

The Sisal plant (Agave) is grown mainly in Africa and Brazil. Agave veracruz is one of the seventy five varieties of general agave family. In India it is found in Assam, Bihar, Bengal, Madras, Maharashtra, Andhra Pradesh and Karnataka. Agave veracruz is grown in abundance in waste lands and landscapes particularly in dry climates of Andhra Pradesh, Karnataka and Maharashtra.

Agave was introduced to India around 1830 by Portugese which was mainly used for hedges along the railway track, paddy and other fields.

Till recently, sisal plant was mainly utilized as a source of fibre, the yield of which is around 3-4 per cent of the weight of the leaves. Remaining 96 per cent is left unutilized and thus wasted.

Sisal leaves are light green in colour with a prominant ashy shade. The leaves grow from a central bud to about 70 to 150 cm. long, 15-25 cm. wide and 0.5 cm. thick at the centre. The leaves have thorns on the edges with sharp tips. Sisal fibre is stiff

and harsh and creamy white in colour. These fibres have about 75 per cent cellulose and 10 per cent lignin. Though the greatest use is for rope and twine, these fibres can be used for pulping, plastic reinforcement etc. In addition sisal leaves are a potential source of more useful products such as hecogenin (a chemical used in the preparation of steroid drugs and harmones) and wax. Fig.1 gives the list of possible products from sisal leaves and Table 1 gives the demand potentials of sisal products.

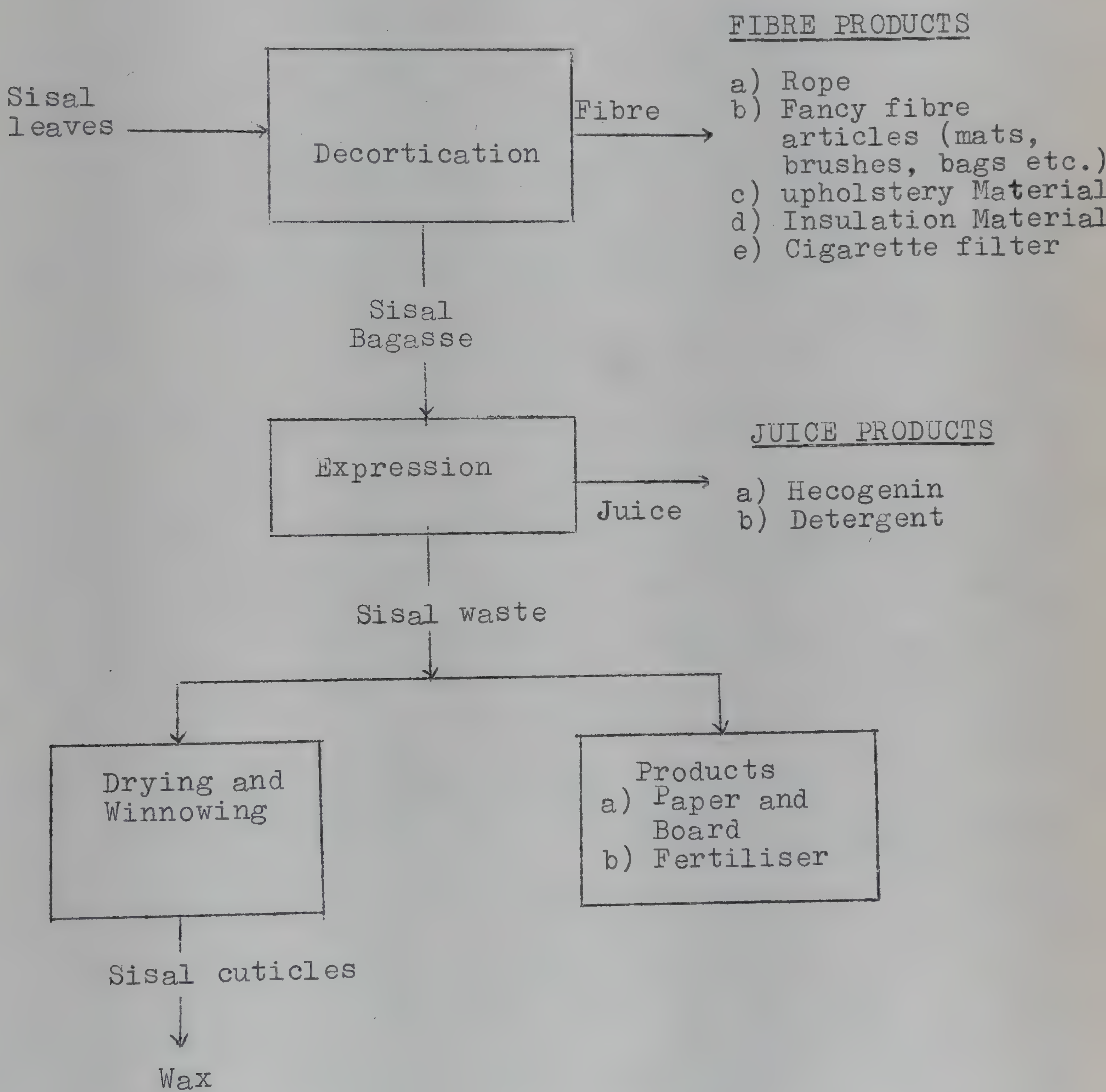
TABLE - 1

DEMAND POTENTIALS OF SISAL PRODUCTS

ITEM	DEMAND in tons (1979)	Market Price Rs./Kg.	Expected price realization to the unit	Growth rate	Impor
Rope	10,000	26	20	5 %	80
Hecogenin	Roughly 20	1100	1000	Not available	100
Wax	335	36	30	About 30 %	100
Hand made paper	20,000-30,000	25-60	15	6 %	10

4.1

Figure - 1 : Products from sisal leaves



Agave species are widely distributed in various villages throughout the state of Karnataka and available throughout the year. Rural industries based on agave leaves appear to be promising projects to increase rural employment though some of the products mentioned in Fig.1 are not highly suitable for manufacture in rural areas due to technological complexities and higher optimum scale of production.

The present investigation was undertaken to collect data with a view to establish best operating conditions to manufacture wax, hecogenin and paper pulp. The ultimate aim is to set up suitable scale industrial units in villages to utilize the sisal plants and generate rural employment.

The average chemical composition of sisal fibre[1] is reported as

cellulose : 77 %

Moisture : 6.2 %

Ash : 1.0 %

Lignin and Pectin : 14.5 %

Extractives : 1.1 %

Annual demand for sisal fibre in India is about 10,000 tor and at present 7,500 tons are imported. [redacted]

PRELIMINARY ECONOMIC ANALYSIS

A preliminary economic analysis has been attempted based on the costs of various sisal products and on the basis of this analysis a two tons/day capacity unit was chosen. The unit would produce 16.5 tons of rope, 0.5 tons of hecogenin, 2.25 tons of wax and 15 tons of hand made paper per year.

Total capital cost works out to be Rs.6,42,000 and operating cost per year Rs.9,85,000.

Total turnover would be Rs.12,22,500 . The plant would break even at 77 per cent capacity utilization. The detailed calculations are not reported at present.

Sensitivity analysis shows that operation of hecogenin division is the most crucial parameter for the profitability of the unit.

Conclusions

The following yields were obtained during the laboratory tests.

Rope	:	3.0 % on leaf weight
Hecogenin	:	0.1 % ''
Paper	:	2.75 % ''
Wax	:	0.375 % ''

Laboratory tests and economic analysis indicate that hecogenin, wax and rope can be produced from sisal leaves profitably. Experiments with pilot plant scale units are in progress and the data obtained on these uni may permit more detailed economic analysis.

References:

1. Kirk and Othmer, Encylopedia of Chemical Technology, Vol. 9, Page 173.

WINNOWER

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Lecture 4.2

Rural Technology Course

W I N N O W E R

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The task of horizontal transfer of technology is gaining momentum of late. The urgent task of technologists therefore is the identification of areas which need technological assistance. The developed technology should be simple and economically viable, so that the user can accept it. As far as possible, in the present socio-economic conditions, the technology should be labour intensive. These requirements of technology transfer to rural areas need an understanding of the current methods adopted to do a job, an assessment as to whether an alternative is necessary and whether the alternative would be better than the existing one. It is believed that Winnowing of grains falls under this category and is a dire requirement in regions where variety of grains are grown.

Winnowing is the art of separation of grains from husk, chaff, broken straw, etc., after the crops are harvested and threshed. There exists a difference in the densities of grains and other materials in the stock threshed. If the mixture containing the seeds and the foreign material is made to fall in a thin layer and if air is made to blow across this layer with some velocity, then higher density grains will be carried to a shorter distance than husk, chaff, etc. This is the principle of separation. It is also sometimes called as aspiration cleaning wherein separation is achieved using the density difference (or buoyancy effect.) The customary method still widely used consists of the use of a winnowing basket, whenever the natural air current favours. Thus, the farmer is left at the mercy of nature's vagaries for the seperation of the grains. Food-grains such as paddy, wheat, ragi, jowar, millets, cereals, corriander,

etc., vary in densities and consequently require varying intensities of wind current for their separation. Many a times these harvested and threshed grains have to be left unseparated and mostly unprotected for want of wind and labour. Availability of labour at times when there are chances of wind blowing has added to the agony of the poor farmer. Often a slight drizzle or dew would spoil the quality of grain and the separated husk which often is a cattle feed. Thus the loss to the farmer is considerable, while the consumer gets a poorer quality of gain -- all because of lack of natural wind on which none can exercise any control. These facts show the dire need of a farm tool like a winnower which must be cost effective, versatile and operationally trouble free.

A cursory look at the process of winnowing operatio would indicate that the feed consisting of grains and unwanted material is poured in a thin layer which is exposed to a controlled and directed wind current so that separation is achieved. The separated grains fall in a heap depending on the angle of repose which is different for different grains. Thus some of the parameters involved in the separation process are the densities of grain and husk, their proportions in the feed, the angles of repose of the grains, the thickness of feed stock layer exposed to air, the direction and intensity of air current. Technically this would be an aerodynamic problem of multicomponent, multiphase flow over or through a matrix of different shaped objects. Writing and solving equations of motion in such a situation appea to be formidable.

The use of winnowing basket is the oldest and stil the most common method of winnowing in India. The other methods used for paddy consist of generating wind by the use of coconut mat or cloth and winnow paddy. Still another approach used consists of throwing the stock of paddy to fal in a circular path, wherein the higher density paddy attaini

higher centrifugal force falls farther away, while the chaff falls nearer. Plat-forms or drums are used so that the stock could be allowed to fall through a greater length. It would be amazing to note that in some areas they put fire to the debris, straw so that they can winnow in the air current thus generated. In some areas the forest is put on fire and wind is generated for winnowing! These are indicative of the helplessness of the farmer.

Units called as combines, thresher-cum-winnower, grain cleaners, winnowers are marketed. These are power operated and are prohibitively expensive and therefore beyond the reach of even big Indian farmers. There are also imported small winnowers developed for specific grains like paddy only, like the one's developed by the International Rice Research Institute, Manila; T.P.I. London, Japanese Model, etc. Their winnowing capacity is rather low and the cost per quintal of paddy winnowed is too high to be afforded. There are other Indian suppliers also. An idea of the available winnowers and their details are summarised in the table annexed. It can be seen from this table that generally they are suited only for certain grains and many of them are laboratory units. Obviously they are not commercialised to any useful degree.

A preliminary survey conducted in some of the areas in Karnataka state showed that:

1. Available units are capital and power intensive and sophisticated, the result being that not many farmers use them. They are mostly found in the Agricultural Universities and in some Government farms.

2. Further they are useful only for certain type of grains like paddy and jowar, while they cannot be used for other grains like ragi, corriander, etc.

3. The farmers also would like to have the seperate chaff and husk to be graded. They use the heavier portions of chaff and husk as cattle feed, while lighter husk is used as a weathering cover for hay stacks and grain storage.

The main grouse of the majority of the farmers is that they are not able to obtain a unit that would winnow most of the grains as it is unreasonable to expect them to possess a number of units that cater to their needs. This is specially so in multiple crop areas. It is felt that transfer of technology is essential to allivate the farmers problem.

An attempt therefore was made to build a unit that could be of general use and versatile. The first unit built was on the lines of the marketed sophisticated units. Being a fore-runner for simpler models to follow and to facilitate collection of information on rate of air supply, velocities and feed rates of stocks of different grains, the unit was powered with one H.P. motor. Only a brief description of the unit is provided here and more details about it are available.

The threshed stock to be winnowed was fed into a hopper which had a fluted rotor rotating inside the hopper at speeds determined by the fan speed. Specially designed wide ducted fan (30 cm x 15 cm) run by a one H.P. motor with speed variation provision provided the necessary air current. It had vibrating seives to grade the grains. Additional control over air supply was obtained using the variable area inlet on the fan. A continued extensive test on this unit provided ideas for development of simpler units that could be cost effective. Similarly the Tropical Products/Unit was also built and is available with K.S.C.S.T of Indian Institute of Science.

/Institute

Having established the technical feasibility, a cost effective (both initial and maintenance) versatile unit (usable for any type of grain separation), that would be in the reach of marginal farmers has been developed. The unit is distinctly simple in construction with no seive shakers, vibrators, force feed rollers, etc., that are prone for troubles and breakdown. Yet, all functions of these are satisfactorily obtained in the present design developed. The heart of the unit developed is a variable area aerodynamic tunnel, with the various profiles adopted doing the functions of the complicated mechanisms found in the available units referred to above. Also the unit is versatile in that all grains could be winnowed satisfactorily with about 95% grain purity. This means a farmer can winnow all types of produce in the same unit.

Figure 1 shows an isometric view of the unit developed. In this unit, the admixture of grain to be winnowed is fed either through the hopper A or through the feed tray X, mounted on the slidable sheet B. The feed rate is controlled by the hand operated flap wheel O. The mixture falls into the wind tunnel due to gravity. The flow passage section of the wind tunnel, and the point of feeding is determined by the shape and position of humps D and E. The radial fan rotatable either by handle V or by motor K (or by a tractor drive) supplies air for the tunnel. The wind velocity is regulated by varying the fan speed. The separated grains slide over the back of the hump E and are discharged through seive G into the collecting hopper H. The separated husk, chaff, etc. is blown off through the front of the tunnel and falls graded. The adjustment needed depends on the grain to be winnowed. The slidable cover provides a variable area and therefore a varied wind speed at a given motor and fan pulley speed. Depending on the grain to be winnowed, the position of sheet B is varied, as also the fan speed.

It was further thought to improve the simplicity and therefore reduction in cost of construction of the unit by adopting an axial fan instead of the radial fan of a lorry. Figure 2 shows the details of this unit. Except for this change in the fan unit with the associated pulley systems, the unit is similar to the one explained above. The specifications of the unit are

Size: 1800 mm x 1500 mm x 650 mm

Materials: M.S. sheets and wooden pulley

Fan drive: Either manual or $\frac{1}{4}$ H.P. single phase motor - 1440 RPM.

Weight: About 400 Kgs.

Wind velocities: Depending on the position of drive belt on the cone pulley, wind speeds of 600 m/min, 500 m/min and 350 m/min are obtainable

Method of operation: Decide whether mannual operation or motor. Fix appropriate pulleys. Change belt to the position sitable for the grain to be winnowed.

Note that at a given speed, the slidable top cover is to be moved further from fan end if heavier grains are to be winnowed. A trial run will establish the slide cover position and the wind speed for the grain stock to be winnowed. The stock to be winnowed is fed from the double hopper, the rate of feeding being regulated by the flap wheel on the hopper. Start winnowing, collecting separated grains falling through the hopper at the bottom of the duct. The chaff, husk, etc. falls in front of the unit graded.

The units have been in use with the farmers for field trails. They have reported successful and satisfactory winnowing of all varieties of grains like paddy, jowar, ragi, corriander, millets, etc. The rate of winnowing is approximately 40 quintals of paddy per hour, 25 quint

of jowar per hour, 10 quintals of ragi per hour. These are the approximate figures provided by the actual users themselves.

The unit is cheap and requires almost no maintenance. It can be operated manually (one man or woman) or with electrical motor ($\frac{1}{4}$ H.P. single phase) or it could also be attached to a tractor with minimum changes and no skill at all. In addition it grades the husk and chaff. The unit can be used both indoors and outdoors including fields. It can winnow all grains.

Table - Available Winnowers

	Make/source	How operated	Other details	Cost
1.	International Rice Research Institute, Manila	0.5 H.P. Motor	One ton of paddy per hour	Not known
2.	Japanese Model	Hand operated	0.65 quintal of paddy per hour	Not known
3.	Petkns Model	7.5 H.P.	0.4 to 0.7 quintals of jowar, paddy per hour	Rs.12,500/-
4.	Crippon Model	1.5 H.P.	2-4 quintals of paddy, jowar/hour	Rs.20,000/-
5.	Tamil Nadu Agricultural University Grain Winnower	1 H.P.	50 quintals of paddy per day	Rs.2200/-
6.	Tropical Products Institute	Hand operated	50 Kg/hr of paddy	Not known
7.	Rajastan Agro Corpn.	15 H.P.	4-5 quintal/hr	Not known
8.	Patiala Winnower	1 H.P.	1 quintal/hr	Rs.2,850/-
9.	Patiala Winnower	2 H.P.	13 quintals/hr	Rs.4,250/-
10.	Punjab Agri. University	3 H.P.	150 quintals/hr	Rs.8,000/-
11.	Cossul, Kanpur	Cycle Winnower	--	Rs.775/-
12.	Kissan Krishi, Kanpur	0.5 H.P.	2 quintal/hr	Rs.3,100/-
13.	Dandekar Brothers, Poona	2 H.P.	10 qunitals/hr	Rs.5,000/-

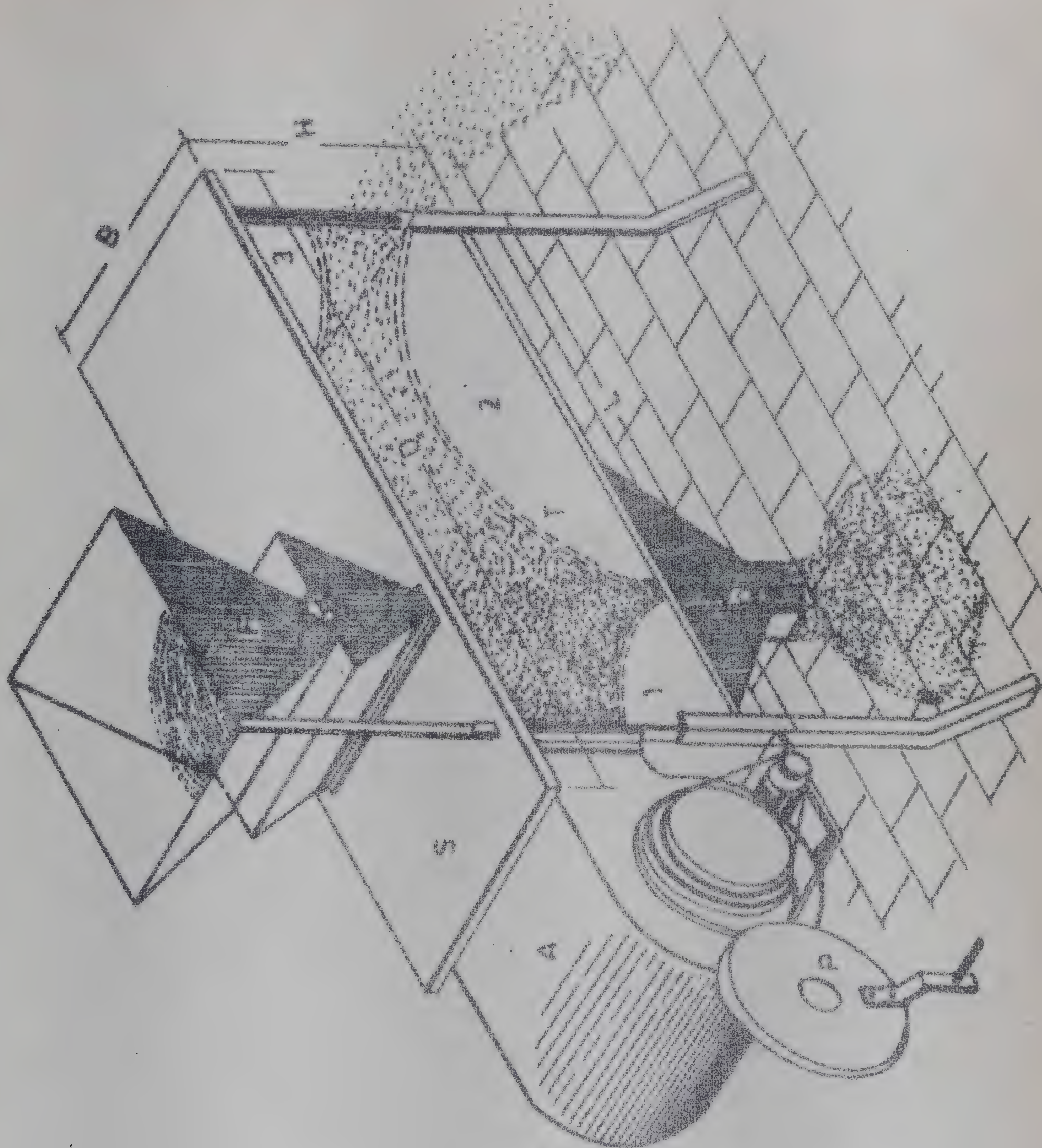

FIG.1.

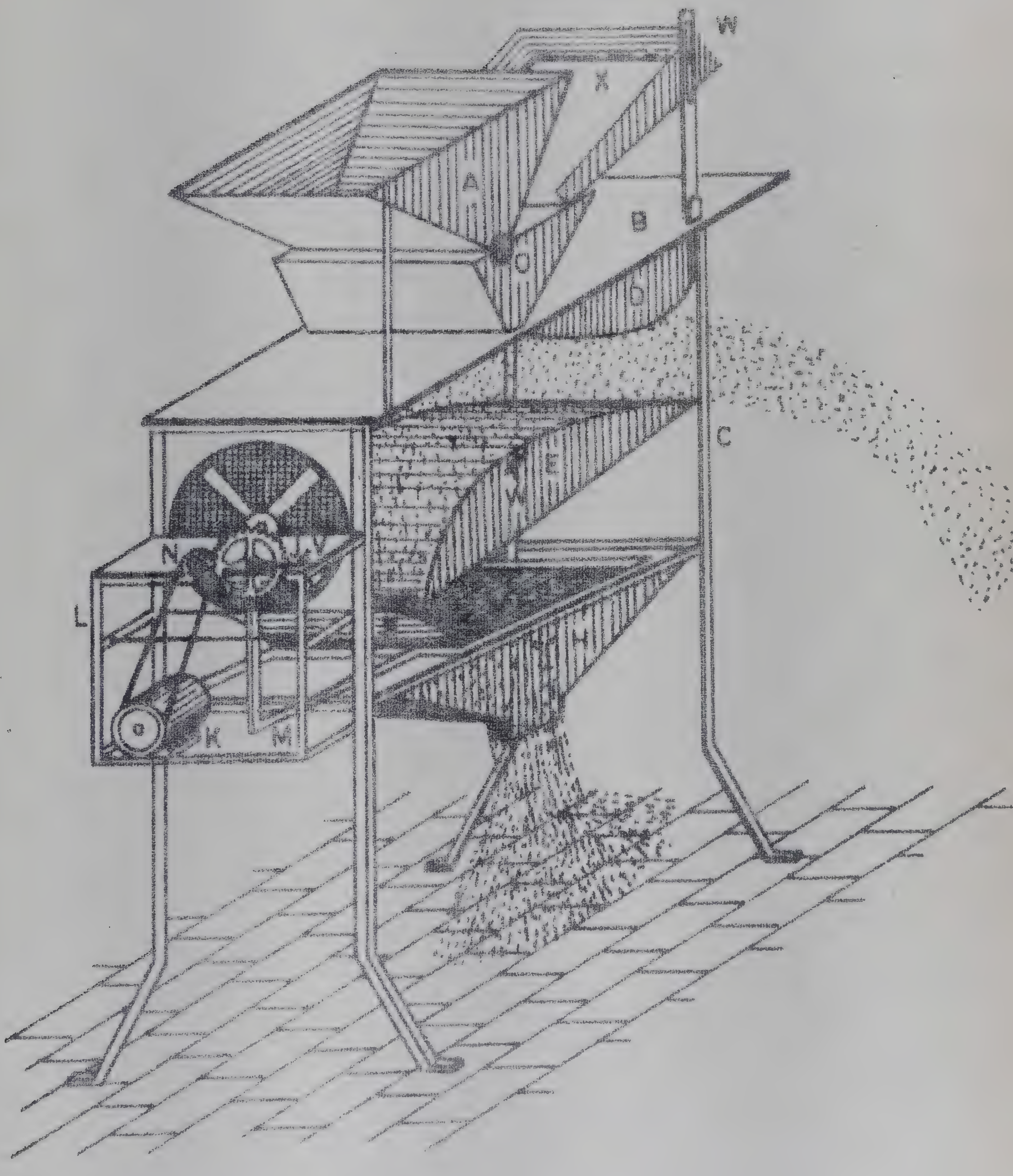

FIG. 2.

LIME-POZZOLANA CEMENTS

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Lecture 6.2

Rural Technology Course

LIME-POZZOLANA CEMENTS

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***

1. Introduction

'Surkhi' or burnt clay pozzolana have been used in India since ancient times to produce a hydraulic cement by mixing it with lime. The term pozzolana has been used to designate reactive siliceous and aluminous material, which react with calcium hydroxide in the presence of moisture to form stable cementitious compounds. Flyash, coalcinder, rice huskash and blast furnace slag are some of the other commonly used pozzolanas . Lime-Surkhi mortar has been well known[1] and the Vani Vilasa Sagar dam (1892) and the Krishnaraja Sagar dam (1911-32) were built in Karnataka using this mortar. There was also an upsurge in research studies on pozzolanas in India since around 1950. The majority of the studies were aimed at replacing a part of portland cement by burnt clay or fly ash pozzolana. Such cements are known as portland pozzolana cements. The combination of cement and pozzolana leads to more impervious & less heat generating concretes . Such cements are ideally suited for the construction of masonry dams. The pozzolana in cement is known to react with the free lime liberated during the hydration of cement.

The value of lime-pozzolona cements, however, has not been adequately recognised, though there have been quite a few publications[2,3] on this subject. There is hardly any organised production of lime-pozzolana mixtures, even though portland pozzolana cements are quite common. There is a definite case for replacing portland cement completely by lime-pozzolana in masonry and foundation constructions. The major reasons to support this view may be listed as under:

1. Masonry mortars need only have a 28 day strength of 40 Kg/cm^2. Such strengths can be easily attained by lime-pozzolana mortar at compárable costs;

2. Lime-pozzolana mixtures can be produced from second grade limestone or kankar deposits which are not suitable for portland cement production;
3. They do not depend on pulverised coal as fuel, which has to be procured from great distance in South and Western India;
4. Lime-pozzolana mixtures can be produced in small, decentralised factories which can generate a greater volume of employment while reducing transport costs.

In this paper, some of the salient properties of lime-pozzolana mortars, costs of production and the potential for th future are discussed.

2. Types of Surkhi-Pozzolana

The Surkhi based pozzolanas may be classified according to the source of the pozzolanic material. The following three sources may be recognised:

a. Waste bricks

b. Waste tiles

c. Burnt clay

A large amount of waste bricks are found both in rural and urban areas and these can be used straight away as pozzolana after powdering them or by wet grinding with lime mortar. Srinivasan[4] points out that powdered brick generally gives inferior surkhis due to lack of control in burning temperature However, use of waste brick surkhis offer a couple of advantage which need to be looked into. Firstly, waste brick surkhis help recycle thermal energy which would otherwise be wasted. Secondly, although brick surkhis lead to mortars of lower stren they should be evaluated with reference to strengths needed in building mortars and the costs at which these strengths are obtained. It is quite possible that lime-surkhi mortars with brick surkhis are cost effective in many situations. Waste tiles are generally found in factories producing mangalore tile and can lead to surkhis of good strength. They can be used to produce lime-pozzolana cements in moderate quantities.

The quantities of surkhi produced from waste products of the brick and tiles industry is generally limited. If the demand for surkhi is higher, production of burnt clays will have to be resorted to. The optimum temperatures for the burning of clays depends on the predominant clay mineral. Montmorillonite clays are to be burnt in the range of 600-800°C while Kaolinite clays are to burnt in the range of 700-800°C.[5] Since soils contain combinations of different minerals, the optimum temperature has to be determined for each soil.

3. Strength of Lime-Surkhi mortars

a. Influence of type of Surkhi:

Five different surkhi types were selected for purposes of comparison:

(i) Fat-clay from Ungra village, Kunigal taluk
(ii) Red soil from Keelara village, Kunigal taluk
(iii) Brick surkhi from Bangalore
(iv) Brick surkhi from Ungra village, Kunigal taluk
(v) Tile surkhi from Yelahanka

The soils from Ungra and Keelara villages were burnt in a laboratory muffle furnace at different temperatures to determine optimum burning temperatures. The strengths of mortars from the various surkhis so produced are presented in Table 1.

It can be seen that the Lime-Surkhi mortar strength can vary over wide limits depending on the soil type and the mode of burning. Except the coarser brick-surkhi, all the samples have shown 28 day strengths of more than 40 Kg/cm^2. The feasibility of using lime-surkhi mortars for masonry work is hence clearly demonstrated.

b. Influence of fumes constituents:

Table-2 shows the effect of using fumes constituents of burnt clay on the mortar strengths. The strength of the mortar increases by about 25% when the proportion of fines in the

Table-1 STRENGTH OF LIME-SURKHI MORTARS

W/c ratio = 0.

Average compresive strength kg/

Soil/surkhi source	Temperature of burning and duration	Particle size	Mortar proportion by weight, Sand: Lime:surkhi:	7 days	28 days	9
clay, ungra	600° C; 4 hours	<90 μ	1 : 2 : 9	23.5	55.7	8
" "	700° C; 4 hours	<90 μ	1 : 2 : 9	28.9	57.5	8
" "	800° C; 4 hours	<90 μ	1 : 2 : 9	16.3	41.9	7
Red soil, Keelara	600° C; 4 hours	<90 μ	1 : 2 : 9	26.4	45.8	
" "	700° C; 4 hours	<90 μ	1 : 2 : 9	19.6	44.5	
" "	900° C; 4 hours	<90 μ	1 : 2 : 9	31.8	54.5	7
Brick-Surkhi Ungra	-	<600 μ	1 : 2 : 9	12.2	22.4	
Brik-Surkhi Bangalore	-	<90 μ	1 : 2 : 9	22.7	51.0	
Tile-Surkhi Yelahanka		<90 μ	1 : 2 : 9	29.5	59.0	

Table-2 EFFECT OF FINER CONSTITUTENTS

Soil Sample	Burning temperature	Particle size	Mortar proportion Lime:Surkhi:Sand	28 day strength kg/cm^2
at clay, ngra	600°C	$<90\ \mu$	1 : 2 : 9	55.7
"	600°C	$<53\ \mu$	1 : 2 : 9	72.15
"	700°C	$<90\ \mu$	1 : 2 : 9	57.5
"	700°C	$<53\ \mu$	1 : 2 : 9	71.2

surkhi is increased. This clearly shows that the highly reactiv constituent are present in the finer fractions of the surkhi. T reactive silica and alumina in the surkhi are produced by the burning of the clay content of the soil and it appears that any approach to increase the proportion of clayey materials in the surkhi will lead to an increased strength in the mortar.

c. The effect of intergrinding lime-surkhi:

The Indian literature on lime-surkhi mortars has generally been silent on the process of mixing lime with surkhi. The conve ional mode of mortar production involved either grinding the mi wet mortar in a bullock driven mortar mill (chakki: Hindi; Gare Kaluve: Kannada) or in a motorised pan mill. The mortar grinding upto about 60 minutes was found to be beneficial while grinding for larger durations lead to decreased strengths probably due to the fact that extended wet grinding starts inte ing with the process of setting. Mehta[6] noted that inter-grinding of a dry mixture of lime and rice husk ash leads to significant strength improvements. Recently[7], a study carried out at the National Institute of Engineering, Mysore showed tha with a certain broken tile pozzolana, seven hours of inter-grinding lime and pozzolana gave a 28 day strength of 180 Kg/cm The intergrinding was carried out in a laboratory attrition mac The results of a similar effort of intergrinding at the Departm of Civil Engineering, Indian Institute of Science are shown in Table-3. While the results are not spectacular, an almost 40% strength increase in the 28 day results are noticed with 30 min intergrinding. Extended intergrinding did not lead to increase strengths.

d. Effect of water-cement ratio:

The earlier results have been quoted for a writer to lime-p lana ratio of 0.5. In practice, the workability of mortars wit a water proportion will be extremely poor and larger amounts of water need to be added. The influence of increasing amounts o water on the strengths is shown in Table-4. A mortar proporti

Table-3 : EFFECT OF INTERGRINDING LIME & SURKHI

Type of surkhi	Particles size before intergrinding	Duration of intergrinding in a ball mill	Compressing strength Kg/cm^2		
			7 days	28 days	90days
Waste tiles	<90 μ	0.0	26.2	55.7	74.0
" "	<90 μ	5 minutes	29.5	59.0	-
" "	<90 μ	30 minutes	39.3	77.2	97.6
" "	<90 μ	120 minutes	38.0	73.0	-

Table-4 : EFFECT OF WATER /CEMENT RATIO

Type of Surkhi	Particle size	/lime-pozzolane by weight	Strength kg/cm^2	
			7 days	28 days
Waste tiles	<90 μ	0.5	29.5	59.0
-"-	<90 μ	0.67	26.9	53.8
-"-	<90 μ	0.75	17.9	44.3
-"-	<90 μ	1.0	14.2	35.6

of 1:2:6 by volume has been used in this test.

The drastic decrease in strength with increasing water content may be noted. A water /cement ratio of 0.75 may be used practice as a compromise between strength and workability requirements.

4. Energy in Mortars

It is desirable to compare a lime-pozzolana mortar with equivalent cement mortar from the energy angle. Assuming that lime-pozzolana is produced in a small scale plant using firewood as the fuel, the energy in lime-pozzolana may be calculated as follows.

(i) Energy in lime:

A Kankar with 80% Calcium Carbonate is considered to be the lime source. If the efficiency of calcination is 75%, each kilogram of Kankar will give 0.8 x .75 x 0.74 = 0.444 Kg of Calcium Hydroxide. If the firewood used is 0.4 Kg per kilogram Kankar, the thermal energy input, per kilogram of $Ca(OH)_2$ =

$$0.4 \times 4000/.444 = 3604 \text{ Kcal.}$$

(Average thermal energy in firewood = 4000Kcal/Kg)

(ii) Energy in surkhi:

A surkhi which needs around 700° C for best lime reactivity require about 10% by weight of firewood for burning operations Accordingly, the thermal energy per kilogram of surkhi = 0.1 x 4000 = 400 Kcal.

(iii) Energy in lime-surkhi mortar:

To produce a 40 Kg/Cm^2 mortar, one could use a 1:2:6 mix by volume with a water-cement ratio of 0.75. Such a large amount water is needed for satisfactory consistency in the mortar. cubic meter of each mortar will contain 0.813 cu. m of sand, .271 cu. m of surkhi and 0.136 cu. m of lime. The weight of t surkhi would be 216 Kg and that of lime 81 Kg. Using the ener values of lime and surkhi, the thermal energy per cu. m of lim surkhi mortar = 3.78×10^5 K. cal.

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(iv) Energy in cement mortar:

A 1:6 cement mortar would be comparable to the above lime-pozzolane mortar in strength. A cubic meter of such a cement mortar would then have .167 cu. m (217 Kg) of cement. The corresponding thermal energy per cu. m of mortar = 217 x 1892 = 4.1×10^5 Kcal. The calculation shows that the lime-surkhi mortar is marginally superior to the cement mortar from the point of view of energy conservation. It is interesting to note that this happens, even though the lime and surkhi burning operations are far more inefficient in comparison with the large scale production of cement. The energy situation with lime-surkhi is advantageous in more ways than one.

a. Firstly, the decentralised lime-surkhi production uses firewood, which is a lower grade fuel than coal. The energies and costs involved in the transport of coal is avoided.

b. Secondly, the small scale, decentralised production of lime-surkhi facilitates distribution and hardly any energy need be spent in the delivering the product to the consumer. However, the highly centralised, large scale production of portland cement will entail long haulages before it can reach the consumer. This will mean an additional 10 to 15% thermal energy consumption (in the form of an imported fuel like diesel oil).

5. A village level lime-surkhi plant

The details of a possible small scale, lime-surkhi plant for rural application is briefly discussed. Some of the data for this analysis are based on the experience gained in trial burning of lime and clay at the Ungra Extension Centre, of the Indian Institute of Science.

The production process consists essentially of burning lime and clay separately in a kiln using firewood as the fuel. The lime is then slaked and mixed with powdered surkhi and interground in a ball mill. The details of the plant are given below.

a. The kiln

The kiln for lime and clay burning is circular and has an

internal diameter of 0.9 m and height 3.2 m. It can burn 800 k
Kankar or 1200 kgs of clay at a time. The lime burning needs 4
by weight of firewood while clay burning needs 10% by weight of
wood to achieve about 700°C burning temperature.

b. <u>Platform for surkhi grinding</u>

An annular concrete platform of diameter 3.6 m and width 1
is used to crush balls of burnt clay (or even brick bats) usi
bullock driven stone roller. Such stone rollers are normally
available in villages for threshing operations. This platfor
grind surkhi to less than 600 size.

c. <u>Ball mill</u>

A small scale ball mill with a capacity of about 50 Kg cha
can be used for fine grinding of surkhi and surkhi plus lime.
A ball mill of this size can be easily driven using the spare
capacity in a village flour mill. An attempt is being made in
the Ungra Extension Centre to use a bullock driven ball mill.
The investment costs for such an installation can be estimated
as follows:

<u>Capital investment</u>

Lime kiln (1T)	:	Rs 2000.00
Grinding platform and stone roller	:	1000.00
Ball mill and animal power gear	:	5000.00
Total capital	:	Rs 8000.00

<u>Running costs</u>

The running costs of the plant can be worked out as follo
Data is based on the Ungra experiments:

Table-5 : COSTS OF LIME-SURKHI PRODUCTION

Operation	Labour md	Animal power bd	Cost Rs.	No. of days
Kankar transport 1 Km, 1.0T	0.5	2.0	15.0	0.5
Firewood procurement & transport 450 Kg	2.0	2.0	115.0	1.0

contd.

Operation	Labour md	Animal power bd	Cost Rs-	No. of days
Chopping firewood	4.0	-	20.0	2.0
Lime charging and burning	3.0	-	20.0	1.0
Discharging and slaking	3.0	-	20.0	1.0
Clay transport and(½ Km) briquetting & burning 1.2T	4.0	2.0	55.0	3.0
Roller grinding of surkhi	2.0	2.0	20.0	1.0
Ball milling 200 Kg/day	14.0	28.0	210.0	7.0
Total	32.5 md	(36 bd)	475.00	

Quantity of lime-surkhi produced : 1.4 Tons ground in 8 days
or 1.2 Tons/week

Runnning costs of production/tonne : Rs.396.0
or Rs.0.40/kg.

1 bag of lime-surkhi (35 kgs) will cost Rs.14.00 to produce.

Let return on investment be = 25% per annum
Hence annual return = Rs.2000.00
If the plant works for 20 weeks,
weekly return = Rs.100.00
Return per ton = Rs.83
per kg = Rs.0.083
Therefore, cost of 1 bag = (.483 x 35.0)
= Rs.17.00

======

The above cost analysis assumes that each batch of lime-surkhi production takes 8 days to produce 1.4 tonnes. The various operations listed in Table-5 must be paralleled to achieve this productivity. The table also shows that ball milling using bullock power accounts for the largest item of expenditure. The cost of firewood is the next largest item. Between the two, the thermal and mechanical energy costs account for 70% of the running costs. The costs of lime-surkhi and cement mortars are

compared in Table-6.

Table-6 COMPARISON OF MORTAR COSTS

Mortar	Cement/Lime-surkhi per cu.m of mortar		Sand per cu. m. of mortar		Tota cost per cu.r
	Weights	Cost	Volume	Cost	
				Rs	
Lime-surkhi-sand 1 : 2 : 6 by volume	287 kg	Rs.138.6	.813 cu.m	11.30	Rs
Cement : sand 1 : 6 by volume	217kg	Rs.130.0	1.0cu.m	14.00	Rs

It is seen that the two mortars have practically the same cost However, the lime-surkhi mortar has the advantage of generatin employment to four labourers in the local production of lime-surkhi.

6. Summary

This paper emphasises the usefulness of traditional lime-surkh mortars as a substitute to cement mortars in masonry and plast work. The importance of the evaluation of suitability of soils burning at the right temperature has been shown. The role of grinding in enhancing the strength of mortars is also indicate The energy economy resulting from the use of lime-surkhi morta also indicated. The volume of rural lime-surkhi production ir generating employment at very low capital costs is also shown.

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6.2

THE DESIGN OF WALLS & ROOFS

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Lecture 6.3

Rural Technology Course

THE DESIGN OF WALLS & ROOFS

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1. THE DESIGN OF WALLS

. Introduction

The walls and the roof together represent a major chunk of xpenditure in a building. Any approach to cost reduction must ence concentrate on the design of walls and roofs. In this aper, some considerations in the design of walls for rural ouses will be discussed.

At the outset, it would be useful to list out the various equirements to be met by a wall design. Some of the typical elt needs (performance requirements) of villagers and the oals of development are presented here. The list may not be xhaustive but, hopefully, includes the major shelter needs of rural areas.

. Performance requirements

1. Strength to withstand roof loads & self weight.
2. Resistance to rain erosion.
3. Resistance to moisture penetration/crack free surface.
4. Fire protection.
5. Thermal insulation/mass.
6. Resistance to termite infestation.
7. Status value
8. Ease of maintenance.
9. Low cost.

. Development goals

1. Use of local materials and skills
2. Energy conservation
3. Cost reduction

4. Avoidance of cultural clash
5. Promotion of self help techniques.

An attempt has been made in the following, to evaluate available techniques with reference to the above requirements

2. <u>Performance of current technologies</u>

Some of the currently used wall construction techniques are listed in Table-1, and evaluated against some of the impo ant performance requirements, by assigning grades from A to I The evaluation was based on a rural survey. It is interestin

<u>Table-1 : EVALUATION OF TECHNOLOGIES</u>

	Strength	Dura-bility	Status	Cost redn.	Local matls.	Ener cons
Brick in mud	B	B	B	C	A	C
Brick in cement mortar	A	A	A	D	C	D
Stone in mud	B	A	B	C	B	A
Thatch	C	D	D	A	A	A
Mud wall	C	C	C	A	A	A
Stone pillars and mud wall	B	C	C	A	A	A

<u>Types of Wall Configurations</u>

- CONTINUOUS, LOAD BEARING
  - MASONRY IN MORTAR
    - BRICKS
    - STONES
    - SOIL BLOCKS
      - IN MUD MORT
      - IN LIME-SUR MORTA
  - CAST-IN-SITU WALLS
    - MUD WALLS
    - RAMMED EARTH
    - MUD & BAMBOO

- PILLARS & IN-FILLED WALLS
  - PILLARS
    - STONE SLAB
    - MASONRY
    - FERROCEMENT
    - RAMMED SOIL CEMENT
  - IN-FILLED WALLS
    - MUD
    - RAMMED EARTH
    - SOIL BLOCK MASONRY

note that a mud wall does not meet the felt needs while it is satisfactory from a development angle. A brick wall meets most of the felt needs but is not well tuned to development goals by its demand on energy resources. It is clear that alternatives are needed which can reconcile the conflicts between felt needs and development goals.

A variety of wall configurations are given in the previous page (and above) to generate viable alternatives. It is now possible to achieve a better fit between the need patterns and the corresponding wall designs by virtue of a diversity of solutions presented. The following sections will discuss the cost optimal options in wall designs.

3. Walls of optimal strength

The various wall design alternatives will now be examined with reference to cost reduction by optimising the dimensions. The structural design of walls can be carried out using the National Building Code[1]. The following points highlight the design steps.

1. The basic allowable stress σ_b on a masonry unit is specified on the basis of the brick/block strength and the mortar strength. The lowest value prescribed in the National

Building Code is 2.5Kg/cm^2 for bricks/blocks of 35 Kg/cm^2 in lime/lime-pozzolana mortar.

2. The slenderness ratio (α) (effective of height or length/thickness whichever is smaller) and the eccentricity(e of loading lead to a reduction factor $K(\alpha, e)$
The product $\sigma_b \cdot K(\alpha, e)$ is then the allowable stress to be in wall design.

3. The stresses in the wall to satisfy the following three inequalities.

Axial stress + bending fibre stress $\leq 1.25\ K(\alpha, e)\ \sigma_b$

Axial stress $\leq K(\alpha, e)\ \sigma_b$

Axial stress - bending fibre stress ≥ 0

4. In designing columns, whose area does not exceed 3000 an additional reduction factor of 0.75 + A/12000 to be used, where A is the area of the column in cm^2.

5. The effective height for walls may be taken as 0.85 x Height and that for columns to be taken as 1.0 x Heigh

Load carrying capacity of walls

Typical calculations of carrying capacity of walls will n be made based on extropolations from the National Building Co It will be assumed that the walls are constructed using compacted (stabilised or unstabilised)soil blocks using lime-sur mud mortar. A typical block strength of 25 Kg/cm^2 will be co sidered in the following. Although the National Building Cod does not permit blocks/bricks weakes than 35 Kg/cm^2, one may take note of the fact that single-storeyed buildings constru using bricks of strengths 10 to 15 kg/cm^2 are performing qui satisfactorily. Accordingly, the basic stress for block mas in lime-surkhi mortar is taken to be 1.78 kg/cm^2 (=25x2.5/3 There is inadequate information on masonry in mud mortar, although mud has been used as a building material since ancie time. Some recent studies[2,3] in the Engineering Colleges of Karnataka and at the Department of Civil Engineering, Indian

Institute of Science[4] indicate that the strength of masonry in mud mortar can vary from 6 Kg/cm^2 to 16.7 Kg/cm^2. Besides, many walls in mud mortar have been observed to perform satisfactorily at stresses of the order of 1.0 Kg/cm^2. Accordingly, a presumptive basic stress of 1.0Kg/cm^2 has been used in the calculation made here for walls in mud mortar. The laboratory tests seem to suggest that this value is only a lower bound to the basic stress. The wall strength for masonry in lime-sukhi mortar and in mud mortar for three typical thicknesses are presented in Table-2. Two strength values are obtained for each wall depending on the compressive fibre stress criterion and the zero-tension at the fibre criterion. Figure-1 shows a typical wall cross section with a running load P/metre.

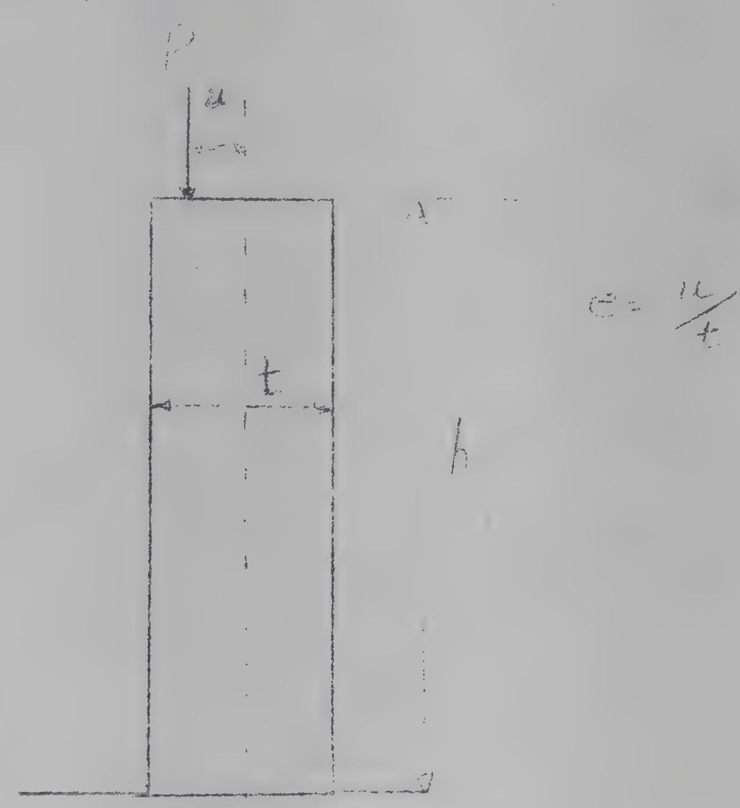

Figure-1: SECTION OF WALL OR PILLAR

The following formulas are used:

$$1.25\,K(\alpha, e)\,\sigma_b - \gamma_w h \times 10^{-4} = 10^{-4} P_1 (1 + 6e)/t \quad \text{--- (1)}$$

$$\gamma_w h = \left| P_2 (1 - 6e)/t \right| \quad (2$$

P_1 is the load which leads to the maximum allowable compress fibre stress and P_2 is the load causing zero-tension at the fibre. The lower of the two values must be considered to be the wall strength. An eccentricity value of $e = u/_t = 0.33$ has been used

Height of wall h = 2.75 m Eccentricity of loading e = 0.33

Thickness of wall in metres	=0.85h/t slenderness R	Reduction factors $k(x_1\ \epsilon)$	Blocks in lime-surkhi mortar $\sigma = 1.78$ kg/cm^2				Blocks in mud mortar $\sigma = 1.0$ kg/cm^1			
			P_1 Kgs	P_2 Kgs	Weight/ Perm. load	Structural effcy.	P_1	P_2	wgt/ p.load	Structural effcy.
0.15	15.6	0.44	269.0	673.0	0.71	0.29	55.0	673.0	0.92	0.08
0.225	10.4	0.74	914.00	1010.0	0.52	0.48	366.0	1010.0	0.73	0.27
0.30	7.8	0.88	1530.0	1346.0	0.46	0.54	664.0	1346.0	0.66	0.34

throughout.

Here u = actual eccentricity in metres
t = wall thickness in metres
α = 0.85h/t : the slenderness ratio
γ_w = density of wall material (assumed to be 1600 kg/m^3)

The table reveals several features of the load carrying capacity of walls:

(i) In thin walls, most of the strength is used up in supporting the weight of the walls, themselves. They can only support small roof loads. Hence the structural efficiency is low.

(ii) Increase in thickness leads to a very rapid increase of load carrying capacity. For instance, in walls of lime-sirkhi mortar, a 50% increase in thickness leads to a three fold increase in load carrying capacity. In mud mortar walls, a 50% thickness increase leads to a six-times stronger wall. This can be attributed to reduction factors which rapidly approach unity as the slenderness ratio decreases. The structural efficiency also improves significantly with increasing thickness.

4. Walls of building

The carrying capacity information presented in Table-2 can now be used to design the walls of a small building for various roof loads. For the sake of clarity, a building with interior dimensions of 3.3m x 5.4m will be considered. The floor area is slightly larger than that of a Janatha house in Karnataka. The width of the roof is assumed to be 4.5 m to include eave overhangs. Assuming a (dead + live) load figure of 150 Kg/m^2, each of the long walls will receive a load of 337 Kg/m. To support such a load, by examining Table-2, it is seen that a wall in lime-surkhi mortar must be around 16 cms. thick, and a wall in mud mortar must be around 21 cms thick. However, a masonry wall thickness cannot be varied continuously to achieve the requisite wall strength. This is due to the fixed sizes of the blocks. (In this case, the blocks are of sizes 30 cms x 15 cms x 10 cms or 30 cms x 22.5 cms x 10 cms). Hence, a wall thickness which is

the nearest upper bound for the required value has to be chos
In this example, the wall in lime-surkhi mortar and mud morta
will both have a thickness of 0.225 metre since this thicknes
the nearest upper bound for the required thicknesses. It is
obvious that this constraint can lead to severe diseconomies
the design of walls. The walls are hence understressed and t
load carrying capacities are never fully utilised. The impli
cations of this on the cost of walls may now be further exami
Three wall materials will now be chosen:

(i) Stabilised soil blocks in lime-surkhi mortar (cost Rs.140/cu.m)

(ii) Stabilised soil blocks in mud mortar (cost Rs.120/cu.m

(iii) Soil blocks in mud mortar (cost Rs.70/cu.m)

The strength of walls (i) and (ii) have been presented in Tab
and the wall (iii) is assumed to have the same strength as
wall (ii). The cost of the walls for the given building for
ous design roof loads are now presented in Figure-2. This fi
demonstrates a number of facts:

a. Increase in roof loads increases the cost of walls invariably.

b. The cost of walls of any material shows a sudden jump whenever wall thickness have to change to accomodate increased loads. For a given material, thicknesses can be optionally selected only for specific roof loads.

c. In some load regimes a stronger material can be cheaper while in certain other regimes a weaker material can be cheaper.

d. It can be stated in general that cost escalations in walls take place due to (i) mismatch between roof loads and wall strengths and (ii) unfavourable cost/strength ratios.

The above conclusions can now be examined with reference
certain simple algebraic relations. It is easy to show that

Cost of wall/m^2 = $C_w \cdot t$

where C_w : cost of wall/m^3

and t : wall thickness in metres.

If the roof load per running metre is P, one could write

$$t = \frac{P \times 10^{-4}}{\sigma_{eff}}$$

where σ_{eff} : effective stress on the wall due to roof load in kg/cm^2

Hence cost of wall /m^2 = $\dfrac{P.C_w \times 10^{-4}}{\sigma_{eff}}$

This formula shows that cost increases directly with P. The effective stress (σ_{eff}) is a measure of the strength utilisation in the wall. It is clear that for a given cost C_w, σ_{eff} has to be as high as possible for cost reduction. It can also be stated that a basis for selecting a new material lies in a search for low values of C_w/σ_{eff}. To carry out a sample comparison of the three wall materials, a couple of loading cases are considered and the resulting values of σ_{eff} etc. are presented in Table-3. The equations (1) and (2) can now be re-examined with reference to σ_{eff} : If the load per running metre P is specified, one can arrive at two values of the optimal wall thickness

$$t_1 = \frac{P \times 10^{-4}(1+6e)}{\{1.25\, K(\alpha, e)\sigma_b - \gamma_w h \times 10^{-4}\}} \qquad \ldots(3)$$

$$t_2 = \frac{P\,|(1-6e)| \times 10^{-4}}{\gamma_w h} \qquad \ldots(4)$$

The selected wall thickness must be the larger of the two values t_1, and t_2. Again since the thickness cannot vary continuously, let t_u, be the nearest upperbound of the larger value of t_1 and t_2.

Then the actual wall thickness

$$t_u = \frac{P \times 10^{-4}(1+6e)}{\{1.25\, K(\alpha, e)\sigma_b - \gamma_w h \times 10^{-4}\}t_1/t_u} \qquad \ldots(5)$$

$$= \frac{P \times 10^{-4}}{\sigma_{eff}}$$

or

$$t_u = \frac{P\,|1-6e| \times 10^{-4}}{\gamma_w h\; t_2/t_u} = \frac{P \times 10^{-4}}{\sigma_{eff_2}} \qquad \ldots(6)$$

Table-3 : COST-EFFECTIVENESS OF WALL MATERIALS

Wall material	P = 225 kg/m			P = 337 kg/m		
	t in m	σ_{eff} kg/cm^2	C_w / σ_{eff}	t in m	σ_{eff} kg/cm^2	C_w / σ_{eff}
Stabilised soil blocks in lime-surkhi mortar	0.15	0.15	933.0	0.225	0.15	933.0
Stabilised soil blocks in mud mortar	0.225	0.1	1200.0	0.225	0.15	800.0
Unstabilised soil blocks in mud mortar	0.225	0.1	700.0	0.225	0.15	467.0

The equations indicate the manner in which the wall cost gets escalated due to various structural reasons. The reasons may be listed as under.

a. A strong and costly material will lead to lower thickness and hence k (λ ,e) becomes small due to increased slenderness, σ_{eff} is effectively low although σ_b is large.

b. $\gamma_w h$ reduces σ_{eff}. However a large reduction in wall density will lead to a situation where equation (4) governs the wall thickness rather than equation (3). And, a very small γ_w must lead to a thicker and costlier wall by equation (4).

c. The desparity between t_1 and t_u and t_2 and t_u will further lead to cost increases due to reduced σ_{eff}.

One can hence conclude that (i) achievement of high wall strength at considerable cost is not advisable. There are a number of factors which lead to the low utilisation of the strength of a strong material in a wall. (ii) A wall made of bricks/blocks is unfavourable for cost reduction since the thickness cannot be varied continuously. Secondly, although the strength of a brick or block is high, σ_{eff} is significantly lower than the block strength and the available masonry strength is further reduced by k (λ, e). (iii) Alternatives offered by cast-in-situs walls and discrete pillars must be explored.

5. Load carrying capacity of discrete pillars

It is possible to carry the roof loads on a system of pillars, obviating the need for load bearing walls. One could provide filler walls in between the pillars using plain mud or mud blocks with hardly any foundation. As listed earlier, several options can be thought of, for the pillars:

a. Use of masonry pillars on discrete footings.

b. Stone slab pillars.

c. Ferrocement pillars.

Sample calculations will now be made for the 3.3m x 5.4m house considered earlier. A roof loading of 150 kg/m^2 (load on pillars : 337 kg/m) is considered for illustration.

a. Masonry pillars

Assume pillars of size 0.45 m x 0.3 m x 2.75 m made of stabilised soil blocks in lime surkhi mortar. Such a pillar can take a load of 647 kg. (calculated as per the National Building Code. $\sigma_b = 1.78$ kg/cm^2, e = 0.33) Hence number of pillars on each long side : $\frac{5.7 \times 337}{647} = 3$

The cost per cu. m (C_w) of these pillars is about Rs.160.00

Since the σ_{eff} for these columns $= \frac{647}{45 \times 30} = 0.48$ kg/cm^2

$$\frac{C_w}{\sigma_{eff}} = \frac{160}{.48} = 333.0$$

This must be compared with the lowest value of 467.0 in Table- However, in the system of pillars the cost of the filler walls must be separately considered.

b. Stone slab pillars

The stone pillars generally have enormous strength and the are rarely designed to take roof loads. Assuming six 0.30 x .08 x 2.75 m pillars, at a cost of Rs.800/m^3, the cost indicat found to be

$$\frac{C_w}{\sigma_{eff}} \quad \frac{800}{647/30 \times 8} = \frac{800}{2.7} = 295.0$$

c. Ferrocement pillars

One can propose angle shaped ferrocement sections of size 10 cms x 10 cms x 2 cms. Again assuming 6 pillars, the σ_{eff} turns out to be , $\neq \frac{647}{40} = 16.2$ kg/cm^2. The cost of ferroc is around Rs.4000/m^3, and hence

$$\frac{C_w}{\sigma_{eff}} = \frac{4000.0}{16.2} = 247.0$$

It can be seen that all the three pillar designs are high cost effective in bearing the load. Although ferrocement is times costlier than masonry pillars per unit volume, it becom cost effective since the stress it can take is 34 times the stress in masonry. Hence very thin ferrocement pillars will d the same job at a lesser cost. One could add the cost of fil

walls made of mud in a traditional manner to get the total cost picture. Assuming a cost of Rs.35.0/cu.m for a mud wall, the cost of the filler wall for the building is Rs.400.00. Adding another Rs.70.00 for bamboo beams over pillars, the total cost of the pillars and filler wall structures is given in Table-4.

Table-4 Cost of pillar-filler wall construction

	Pillars cost Rs	Filler wall Rs	Beams Rs	Total Rs
Masonry a	388.0	400.0	70.0	858.0
Stone slab b	360.0	400.0	70.0	830.0
[illegible] c	288.0	400.0	70.0	758.0

Thus all the three options give cheap walls, comparable in cost to the mud block wall (unstabilised) discussed earlier. However, the foundation cost in pillar design will not be more than Rs.100.00, whereas for the continuous wall, one may have to spend about Rs.450.00 for the foundation. The pillar design has a considerable advantage since the filler wall can be constructed using self-help & very often its cost is only notional and need not be spent by the house building agency. This means that in real terms an expenditure of about Rs.500.00 must be made to get the walls ready. This approach suggests an alternative to the Janath Housing Scheme and the government need only spend Rs.1500/- (Rs.500 for pillars plus Rs.1000.00 for the roof) per house allowing the beneficiary to finish the skeletal construction through self-help.

6. Summary

The above analysis leads to the following general conclusions.

a. The use of traditional brick and stone walls do not lead to low cost alternatives.

b. Although the stabilised soil block is a low energy alternative to burnt brick, it is not cost effective.

c. Walls of plain soil blocks, with suitable protectio against weather, provide low cost alternatives.

d. Use of pillars and in-filled walls can lead to a ver flexible solution. The foundation costs are negligible in thi case.

e. The strength of mud walls and rammed earth (protecte against rain) must be explored in detail for low-cost alternat

f. The roof loads must be less than 100 Kg/m^2 to keep wall costs low.

B. THE DESIGN OF ROOFS

1. Introduction

The roof of a house presents a challenging design situation in under developed countries. The problem of providing roofs for the poor has been aggravated by the obsolescence of traditional technologies, rapidly escalating material costs and the demands/aspirations created by the use of modern, energy intensive materials by the elite. A possible approach to roof design is indicated here, based on an analysis of the requirements and available resources.

2. Roofing needs

Two classes of needs may be considered. Firstly, the performance requirements desired by an individual house owner must be met. Secondly, since roofing for houses represent a large financial outlay, the money spent on roofing should also serve the development needs of the community. A representative list of the performance and development needs are listed below:

a. Performance requirements:

1. Resist dead and live loads - provision of strength
2. Prevent leakage during rain.
3. Fire resistance
4. Resist organic decay
5. Resist termite attack
6. Resist uplift due to wind
7. Provide thermal insulation (summer/winter comfort)
8. Life span of 15 to 20 years at low cost
9. Light roof for cheaper walls and foundation
10. Security: resist breaking in
11. Pleasing appearance
12. Provide status value.

b. Development needs:

1. Use of local materials and skills
2. Conservation of fuel energy
3. Cost reduction
4. Avoid cultural alienation by increased local participation.

The first eight requirements listed against performance represent the response of the roof to the physical and the bi logical environment around it. Provision of these requiremen (performance standards for satisfying these requirements need be evolved.)/ will meet phisical needs. The ninth performance requirement is specifical introduced to help reduce costs in housing the poor. The rem ing performance requirements are essentially social and cultu nature. Such requirements are important from the point of vi of acceptance of innovative roof designs.

The development needs listed emphasize the view point that capital and energy starved economies of under developed ries must aim at self-reliant, low energy growth patterns. fuller utilisation and participation of the enormous human re in dispersed rural communities is central to this approach.

3. Materials, Processes and Forms

The roof of a house can be classified in several different ways. It can be classified on the basis of the mat used, or on the basis of the manner in which it is constructe an the basis of its geometrical form. A large number of roof alternatives can be generated by these three classifications combinations thereof. Consideration of a variety of alterna is essential if the elaborate set of needs has to be satisfie of the possible classifications in the three categories are listed below:

Roofing materials

1. Grasses, reeds and palm thatch.
2. Agro fibres: coir, sisal and bagasse.
3. Bamboo.
4. Palm trunk.
5. Mill sawn timbers.
6. Country tiles.
7. Mangalore tile (factory produced).
8. Soil
9. Stone slab
10. Reinforced concrete.

11. Ferrocement
12. Burnt brick
13. Lime
14. Clothes and membranes
15. Cement asbestos sheets
16. Light roofing sheets
17. Fibre reinforced plastics

<u>Processes</u>

1. Self-help construction
2. In-situ construction
3. Local artisan
4. Prefabricated-transported (non-local)
5. Local industry based construction.
6. Roof structure plus covering
7. Homogeneous roof: structure-cum-covering

<u>Forms</u>

- Sloping roof
  - Rafter and tile
  - Rafter and thatch
  - Bamboo and stabilised soil & plaster
- Flat roof
  - Stone beams and slab/stone slab
  - Timber/Bamboo and soil
  - Reinforced concrete slab
  - Madras terrace
  - Jack arch terrace
  - Prefabricated beam and panel
  - Prefabricated channels
- The Vault/dome and conical roof
  - Mud brick/burnt brick vaults and domes
  - The Igloo
  - Conical thatch
  - Ferrocement/reinforced concrete shell
- Surpended/membrane roof
  - The mongol yurt
  - The Indian Teepee
  - The tent
  - Pneumatic membrane

4. Evaluation of roofing technologies

A number of roofing ideas can be generated by examining listed alternatives. There is, however, a need to evaluate different alternatives against the performance and developme requirements discussed earlier. A rough evaluation is attemp in the foregoing table-5, regarding some of the currently ava able rural roofing technologies.

Table-5 : Performance Evaluation of Roofing Technologies

Needs	Bamboo & Thatch	Rafter & Mangalore Tiles	Timber/ Bamboo & Soil (malige)
Durability	D	B	B
Leakproof	B	B	B
Fire proof	D	B	B
Thermal comfort	A	B	B
Lightness	A	B	D
Status value	D	A	B
Local materials and skills	A	D	A
Fuel conservation	A	C	A
Cost reduction	A	D	D
Cultural acceptability	B	A	B

The three different roofing technologies have been ass suitable grades against each need, based on an opinion surve information in the table can be summarised as follows:

a. The thatched roof is not durable, is exposed to fire hazard and has a low status value;

b. The Mangalore tiled roof satisf most of the felt needs, but depends on non local, energy consuming materials and is costly;

c. The traditional timber and mud roof (the 'malige') is costly and leads to costlier walls and foundations due to its enormous weight. Seems to be otherwise satisfactory.

One way of arriving at roofing alternatives would be to start with the existing roofing forms and introduce modifications/ corrections to improve the shortcomings in their performance. As an illustration three modified roofs can be discussed.

(i) Treated thatch roof

It is possible to improve the durability of thatch by dipping it in a suitable chemical solution. Use of copper-chrome-boric solution was tried at the Ungra Extension Centre. This thatched roof has seen satisfactory service for about 2½ years now. Suggested life : 5 years. It is debatable if a life span of 5 years is adequate for a roof covering. This treatment provides specific protection against termits or fuengal attack. Additional treatment against firehazard is needed. While durability can be improved by treatment, it is not clear if the treated thatch acquires a status value.

(ii) Coir-reinforced cement based tiles

This roof is an attempt to copy the tremendous success of the tiled roof by designing the tile form which can be locally manufactured and which can use agrofibre like coir. This roofing concept has been investigated and successfully developed at the B.D.T. College of Engineering by Mr. N. Revanasiddappa[5,6,7] and his students over the past three years. They have been able to reduce costs and arrive at a roofing tile which is lighter than the Mangalore tile. The new tile makes increased use of local skills and avoids the sever cost escalations due to transportation. Accordingly, the new tile can be considered to be the first step towards a self-reliant roof covering technology. The use of portland cement might be pointed out as a disadvantage of the new technique. It must be observed that the amount of cement used per house is negligibly small. A small fraction of the current cement production in the country is enough to provide for 3 to 4 million cement-tiled houses every year. Again, the possibility of producing alternative cements in villages brightens the prospects of such tiles.

(iii) <u>The bamboo-polythene - stabilised soil roof</u>

This is a roofing concept which tries to resolve the weight problem posed by the soil roof. A relatively thin lay stabilised soil, drastically reduces the weight of the roof c and the roof structure cost is hence reduced. A layer of pol sheet can solve the leakage problems. The stabilised soil can covered by lime-surkhi plaster or thatch to prevent erosion. type of roof has been extensively tried at the Ungra Extensic Center of the Indian Institute of Science.[8]

The three alternative roofs indicate a methodology for arriving at appropriate building techniques by resolving the problems posed by currently used technologies. In the three examples selected, it appears that the cement based tile and stabilised soil roof have the potential of replacing the curr accepted mangalore tiled roofs. It is possible that these ro ideas may undergo further perturbation to be adapted to diffe resource and skill endowments of various regions.

5. <u>Roof loads and the cost of roof structure.</u>

A light roof has been suggested as a desirable objectiv designing rural roofs. The earlier section on walls has show influence of the design roof load on the cost of walls. The fluence of this roof load on the cost of the roof structure w be discussed here. The design roof load may be considered as sum of the dead load and the live load acting on it. For slo roofs the live load can vary between 75 Kg/m^2 and 40 Kg/m^2 (according to the National Building Code.) The smaller load used for slopes of the order 28°.

Sample calculation of roof structures cost are made, as ing that the roof covering is supported on a series of parall bamboos. The room span is assumed to be 'l' metres and each bamboo, a hollow section with outer diameter of 10 cms. and inner diameter 8 cms. If a fibre stress of 200 Kg/cm^2 is all the bamboo will have a moment of resistance of 11,600 kg. cm. required spacing of the bamboo('s') and the cost of the roof

structure are shown in Table-6, as a function of 'q', the design roof load.

Table-6: Cost of Roof Structure

The design roof load Kg/m^2 q	l = 3.0 m		l = 4.0 m	
	s in m	cost per sq.m Rs	s in m	cost per sq.m Rs
50.0	2.1	1.42	1.16	2.6
100.0	1.05	2.86	0.58	5.20
150.0	0.70	4.29	0.39	7.70
250.0	0.40	7.5	0.23	13.0
400.0	0.26	11.5	0.15	20.0

The table shows that the roof structure cost increases linearly with the design roof load. A 30% increase in span leads to a near doubling of the roof structure cost. Although a roof load of 50 Kg/m^2 needs a very cheap structure, the corresponding bamboo spacings of 1.0-2.0 m are unrealistic. Roof coverings spanning this spacing may be problematic. Hence, even if roof loads are less than 100 Kg/m^2, one may have to use spacing o the order of 0.5 to 0.6 m. The roof structure costs are rather high at roof loads in excess of 250 Kg/m^2. Based on these considerations one could specify upper bound design roof load of 150 Kg/m^2 for cost reduction. In other words, the roof weight must not be more than 75 Kg/m^2.

6. Conclusions

a. The weight of a roof covering must not be more than 75 Kg/m^2 for cost reduction.

b. Use of locally manufactured cement based tile and stabilised soil over polythene are two alternatives with a potential to meet roofing needs.

c. The problems of thermal comfort resulting from light roofs needs to be examined carefully.

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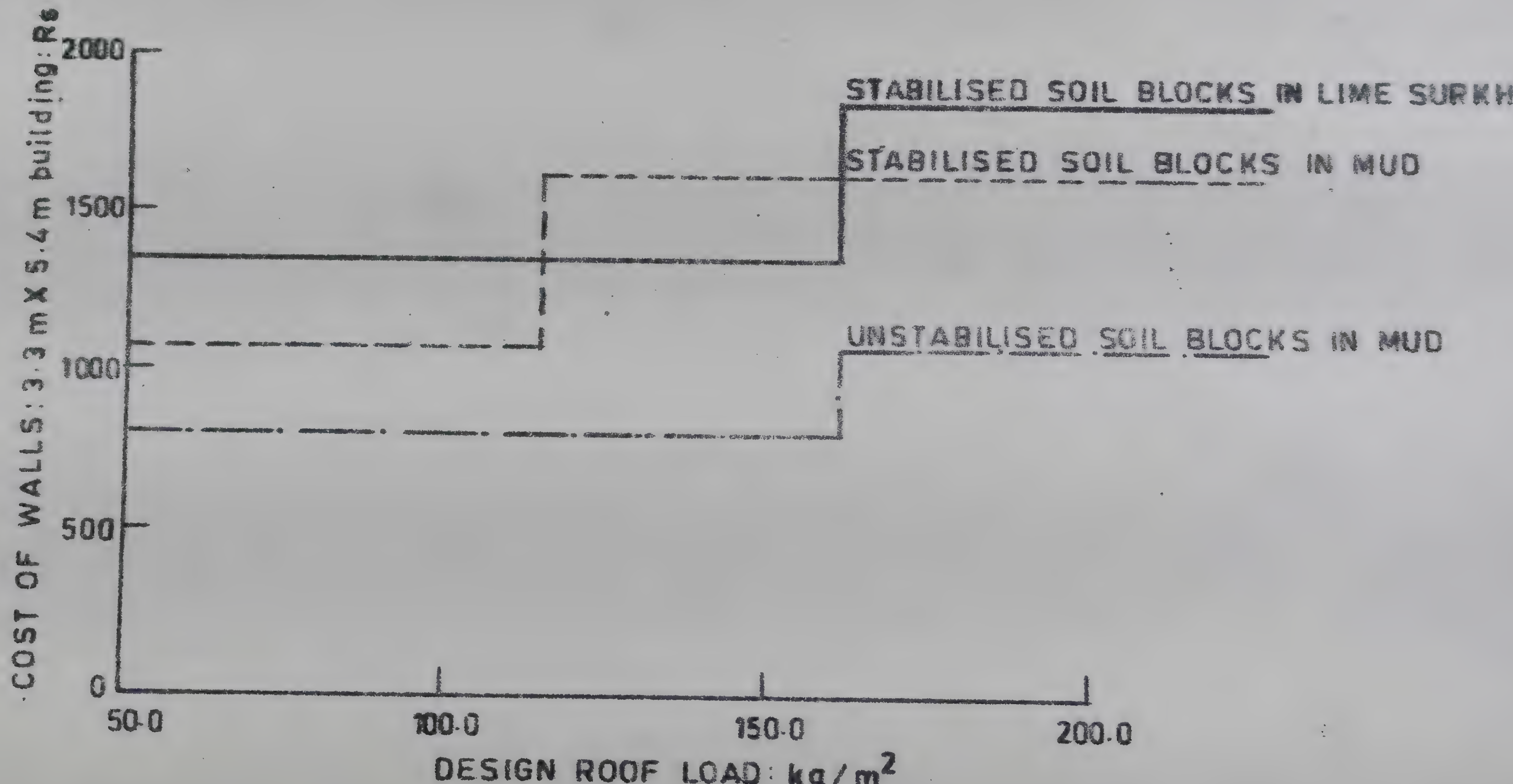

FIG. 2 - COST OF WALLS Vs ROOF LOAD

THE DESIGN OF A SOIL COMPACTION RAM FOR RURAL HOUSING

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Lecture 6.8
Rural Technology Course

1. INTRODUCTION

Soil has always been used extensively as the basic material for wall construction in traditional houses. It's abundant availability almost every where and low cost have lead to it's wide-spread use. But, it is not free from drawbacks as a construction material. The major disadvantage of soil lies in it's vulnerability to exposure to rain. Mudwalls are hence not considered to be durable (whether the wall is of puddled soil construction or of unburnt bricks laid in mud mortar).

Burning processes have been used since ancient times to render the soil immune to strength losses due to moisture absorption. Bricks and tiles represent the typical traditional materials, stabilised against exposure to rain. Although the performance of such materials is very satisfactory, the high levels of fuel energy consumption, which they entail, is quite unfavourable from the environmental angle. For instance, a brick house of 50 square meter plinth area will need about 5 tons of firewood (Jagadish 1979) for the burning operations. This fact alone prevents the use of bricks in a massive way for house building purposes. If bricks are used extensively for house building today, one must take note of the fact that, the number of brick houses built every year is nowhere near the real housing demand. Any attempt to meet the housing demand by

brick houses is just not feasible in view of the energy constraints. The need for an alternative way of using soil in wall construction is hence clear.

Soil can very often be 'stabilised' by cementitious admixtures. Stabilisation means a favourable alteration in the volume change and strength loss characteristics, generally suffered by soil on saturation. This suggests the use of cementitious admixtures while making soil bricks/blocks which are not burnt. The most commonly used stabilisers are portland cement, lime and lime-pozzolona cements. The properties of the stabilised blocks can be improved further by compacting the soil in a suitable machine. The process of compaction generally leads to higher strength and lesser moisture absorpti

2. MACHINES FOR SOIL-BLOCK PRODUCTION

It is possible to produce compacted soil blocks by directly pressing soil into a mould using a tamping rod. The degree of compaction, however cannot be easily controlled in this process. Compaction in a ram which has a predetermined stroke lengh is essential for controlled production of blocks. Two such machines are in use the world over: viz the (i) CINVA RAM and the (ii) ELLSON BLOCK MASTER. The first one was developed in Colombia, and the second machine of South African orig is currently manufactured at Rajkot. Both the machines are
mechanism to produce the l
manually operated and use the toggle/mechanical advantage

needed in soil compaction. Although both the machines have been used successfully in producing compacted soil blocks in many countries, a few disadvantages were observed while using them. For instance the Cinva Ram uses a fixed mould and the block size cannot be changed. The Ellson block master, on the other hand uses interchangable moulds. However, Ellson block master weighs 207 Kgs., while the Cinva Ram weighs only 68 Kgs. Thus a need for cheap machine, which could combine the lightness of Cinva Ram with the flexibility of Ellson block mater, was felt. Again, a machine which is to be be used in villages needs a decentralised production base. It is unrealistic to procure a simple device like the soil compaction machine from a great distance. This paper describes the salient design features of such an alternative machine: the ASTRAM.

3. COMPACTION CHARACTERISTICS OF SOILS

The compaction of soils is usually studied with referance to a standard test like the proctor's compaction test, where a definite amount of energy is provided to the soil while compacting it. Although such a test reveals the optimum moisture content of the soil and the corresponding density for the standard energy input, it does not yield any information on the force needed in a static compaction operation. It is quite likely that this force depends on the size of soil mass under compaction. A direct test to evaluate the force on

soil mass during compaction is hence desirable. Such a test was first suggested and carried out by Karnik (1979). The task of the soil compaction machine then is to produce the desired force variation. Thus the force-deflection relationship of the soil mass is a basic prerequisite in designing the machine.

A few tests were carried out with two soils to ascertain the nature of force during compaction. Soil was first loosely filled in a mould of size 30 cms x 14.5 cms x 16 cms. It was then compacted in a universal testing machine, and the force-ram-stroke curve was obtained. All the tests were carried out at the optimum moisture content. The curves for different values of the initial soil mass are shown in figures 1 and 2. The grain size distributions of the two soils tested are shown in figure 3. Two types of soils were taken up for these tests (a) Red soil and (b) sandy soil made by mixing sand and red soil. The figures reveal several features of static soil compaction. The compaction force increases slowly in the beginning, but attains very large values at the completion of stroke. Larger forces are needed to achieve higher dry densit The sandy soil used in the test needs nearly 3 to 4 times the maximum force needed for red soil. For the tested cases, the maximum force varies between 1.4 T (Red soil, dry density 1.6 to 17.0 T (sandy soil, dry density 1.90). It is now clear th the range of forces needed for different soils will vary over wide limits. It may be difficult to compact sandy soils to

a high density as the force needed would be very large. The tests also show that with larger clay content compaction forces are smaller.

4. THE ASTRAM

The force-ram stroke curves for soils shown in figures 1 and 2 indicate that large forces are necessary towards the end of the compaction stroke. This means that the mechanism for a manually operated machine should be capable of providing a gradually increasing force-amplification as the compaction proceeds. The well known toggle mechanism is ideally suited for this purpose. Figure 4 shows the mechanisms used for the Ellson Block master and the ASTRAM. An improved version of the Ellson block master mechanism has been selected for the Astram. The Astram mechanism provides a better mechanical advantage to reduce the manual force needed during compaction. The force-amplification vs ram stroke for the two mechanisms is shown in figure 5. The magnitude of the force to be applied at the lever end to produce a 9 kgs block as a function of the compaction-stroke is shown in figure 6, for the two machines. The advantage of the Astram mechanism over the other can be seen clearly in these figures. The human effort variation with stroke, as shown in Fig.6 leads to a couple of important conclusions regarding compacted soil block production. Firstly, the effort gradually increases with stroke reaching a maximum when 90% of the stroke is completed. The effort diminishes

rapidly during the last 10% of the stroke. The maximum effort needed for sandy soil varies between 60 to 70 Kgs and that for red soil varies between 20 to 25 Kgs. Secondly the maximum effort that can be produced by an average Indian labourer over short durations (of the order of a few seconds) was found to be around 50 Kgs based on a laboratory test. One can expect a lesser value for the maximum effort when sustained compaction operations have to be carried out. It is hence clear that the sandy soil used in these tests cannot be compacted by the effort of one person in these machines. Consequently the machine need not be designed for the large forces needed for sandy soils. A maximum compaction forces of 10 tons has been considered, which is commensurate with the maximum human effort that can be produced.

One of the objectives of designing the Astram was to produce a low-cost machine. The frame of the ram has to be designed to withstand the upward forces generated during compaction. Based on the estimated maximum compaction force of 10 tons, the frame of the Astram was carefully designed and the resulting steel sections were significantly smaller than the ones in Ellson-Block master. Again the Ellson-block master is heavier, since the vertical force on the lid is transfered to the four columns of the frame. In the Astram, however, the shell of the mould itself is utilised to transfer the lid forces to the frame. This feature makes the mould mounting relatively simpler and reduce the weight

of the machine further. The Astram with a weight of 108 Kgs is only half as heavy as the Ellosn-Block master. Plate 1 shows the Astram with mould attached. Plate 2 to 4 show the three sequences in soil block production using the Astram.

The machine has been provided with two moulds capable of producing two block sizes: 30 cm x 14.5 cm x 10 cm and 30 cm x 22.5 x 10 cm. The moulds can be interchanged easily. Each mould has a lid closing lever mechanism which uses an eccentric shaft. The machine has already undergone field testing and has shown satisfactory performance.

5. BLOCK MAKING IN ASTRAM

The block making process using the Astram involves a sequence of activities. The various activities can be listed as follows.

(i) Mixing/preparing the soil

(ii) Loading the scoop

(iii) Filling the machine mould

(iv) Lid closing and compaction

(v) Lid opening and ejection

(vi) Stacking the block.

The block making process using the Astram was monitored during the construction of a building. The time needed for each activity of blockmaking is given in table -1.

The block manufacturing is generally done in batches,

6.2

where each batch operation consists of (i) Mixing/preparing an amount of soil for 'n' blocks and (ii) making the blocks in the machine.

The batch operation is needed for the following reasons.

(i) If the soil contains cement as a stabiliser, the batch of mixed soil should be compacted within the setting time of cement.

(ii) It is difficult to achieve a good intimate mix with large quantities of soil.

The total peoduction of blocks per day depends on the number of labourers working at the machine and the number of labourers preparing the soil. In order to minimise the production cost, a study of the various combinations of labourers working at the machine and at soil preparation was carried out.

Figures 7 to 9 show the activity networks and labour utilisation diagrams of various combinations of labourers working at the machine. Figures 7 and 8 show the activity netweork and labour utilisation diagrams for making one block with 2 and 3 labourers respectively. When 2 labourers are making blocks, there are no parallel activities, and the critical path will be along a straight line, hence the total time needed for making one block is more (51.7 seconds). When 3 labourers are involved, some of the activities are carried out in parallel and the time taken per block comes down to 30.1 seconds. Figure 9

6.8

shows the activity network and labour utlisation diagram for making one block when 4 labourers are working at the machine. There are some parallel activities even here, but even then the total time needed for making one block is 30.1 seconds. The labour utilisation with four labourers at the machine is not as efficient as with three labourers.

Figures 10 to 14 show the activity networks for making one batch of blocks (25) for various combinations of labourers working at the machine and preparing the soil. The activity net-works clearly indicate that, in general the time needed for making one batch of blocks (25). is less than the time required for preparing the soil (15 pans) for that batch. The total time needed for completion of the batch operation is hence controlled by the soil preparation activity.

Making use of the above mentioned netwroks, the total production of blocks per day, and labour cost per block with the various combinations of labourers is worked out, and presented in table 2. A plot of labour cost per block, total production per day, and block production per day per labourer is shown in figure 15.

The graphs in Figure 15 clearly show influence of number of labourers on productivity. The cost per block is minimum (8 paise) and the number of blocks per labourer is maximum (125) when three labourers are working. It must be noted that even here, the machine is idling most of the time

6.8

since the operation of soil preparation determines the rate of block production. It is thus clear that any attempt at increasing the productivity must look for speeding up/mechanisation of the soil mixing. In the event of more efficient soil preparation, the productivity of the same machine could easily be doubled.

7. CONCLUSIONS:

The compaction tests on soils and the analysis of toggle mechanisms have shown that:

(i) The maximum force needed in static compaction can range between 1.4 T to 17.0 T depending on the soil constitutic and the final density of the compacted soil.

(ii) The human effort needed for compaction reaches a maximum when 90% of the stroke has been completed, both in Ellsor Block Master and in Astram. For highly sandy soils (70% sand) the maximum effort needed is of the order 60 to 70 Kgs and such an effort can hardly be produced by one person in Indian conditions.

Those conclusions have a direct bearing on the design of rams for compacted soil blocks.

The study of the block making process using the Astram shows that

((i) At least two labourers are needed for making the blocks with the machine.

(ii) The labour cost per block is low when 3 labourers are working at the machine with a production of 375 blocks per day.

6.8

(iii) To increase production of blocks per day with the same machine, the soil preparation activity should be mechanised and its time should be reduced per batch. The question of further improving the productivity of the machine does not arise until a soil mixing/preparing time of 12.54 minutes per batch of 25 blocks can be achieved.

Table 1. DURATION OF ACTIVITIES

Sl No.	Activity	Average time required	Standard deviation
1	Mixing the soil (15 pans)		
	(a) one person	31 minutes	
	(b) two persons	26 minutes	
	(c) three persons	22 "	
2	Loading the scoop	7.6 seconds	3.34
3	Filling the machine mould	14.7 "	4.71
4	Lid closing and compaction	8.1 "	3.41
5	Lid opening and ejection	7.3 "	3.57
6	Stacking the block	14.0 "	3.33

Table 2. ANALYSIS OF BLOCK PRODUCTION

Total number of labourers	number of labourers for soil preparation	number of labourers for block making	Time for making 25 blocks (in minutes)	Cost of labo per block in paise
2	2	2	47.5	8.9
3	1	2	31.0	8.0
4	2	2	26.0	8.9
5	3	2	22.0	9.5
6	3	3	22.0	11.4

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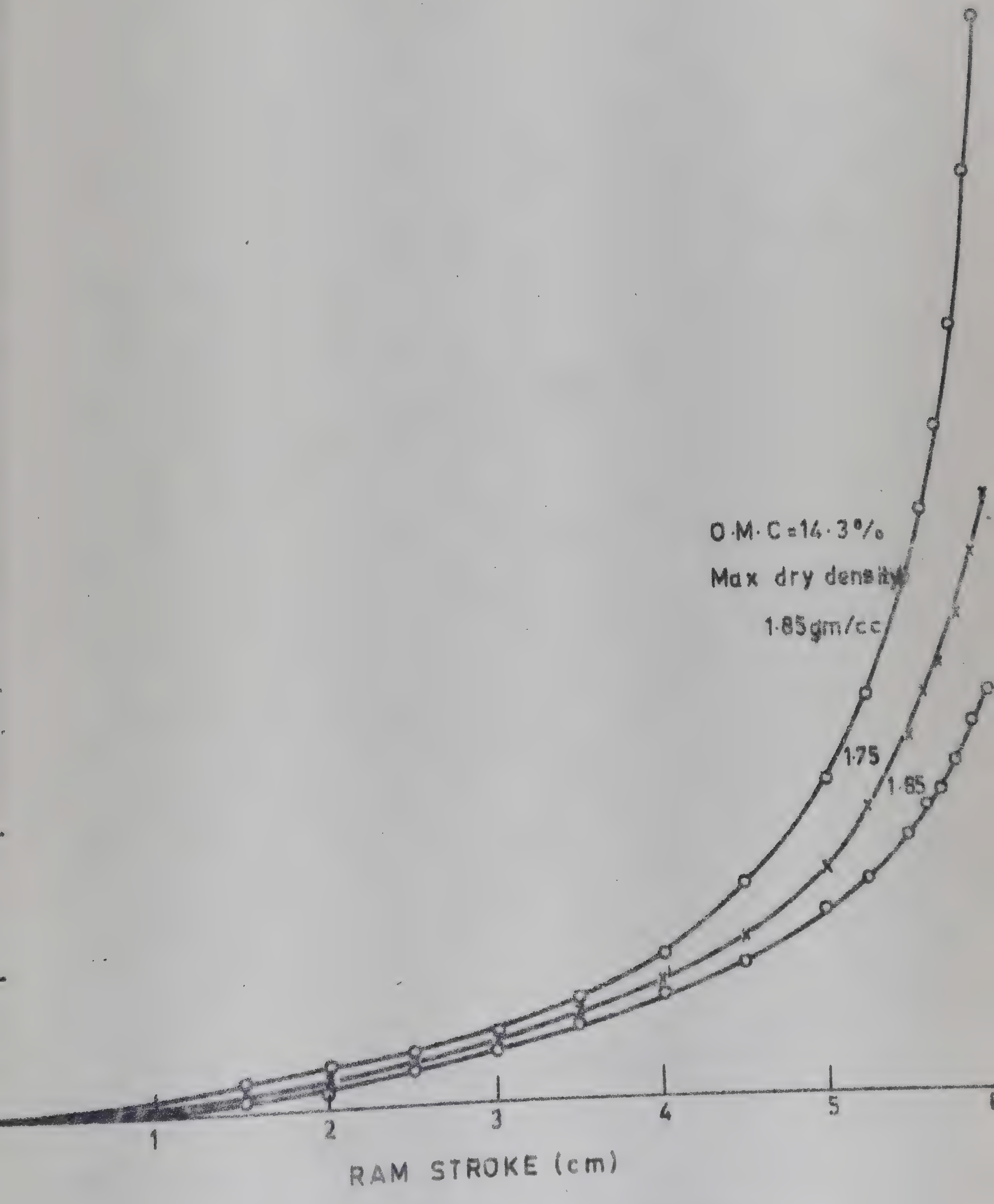


FIG·1· COMPACTION FORCE FOR REDSOIL

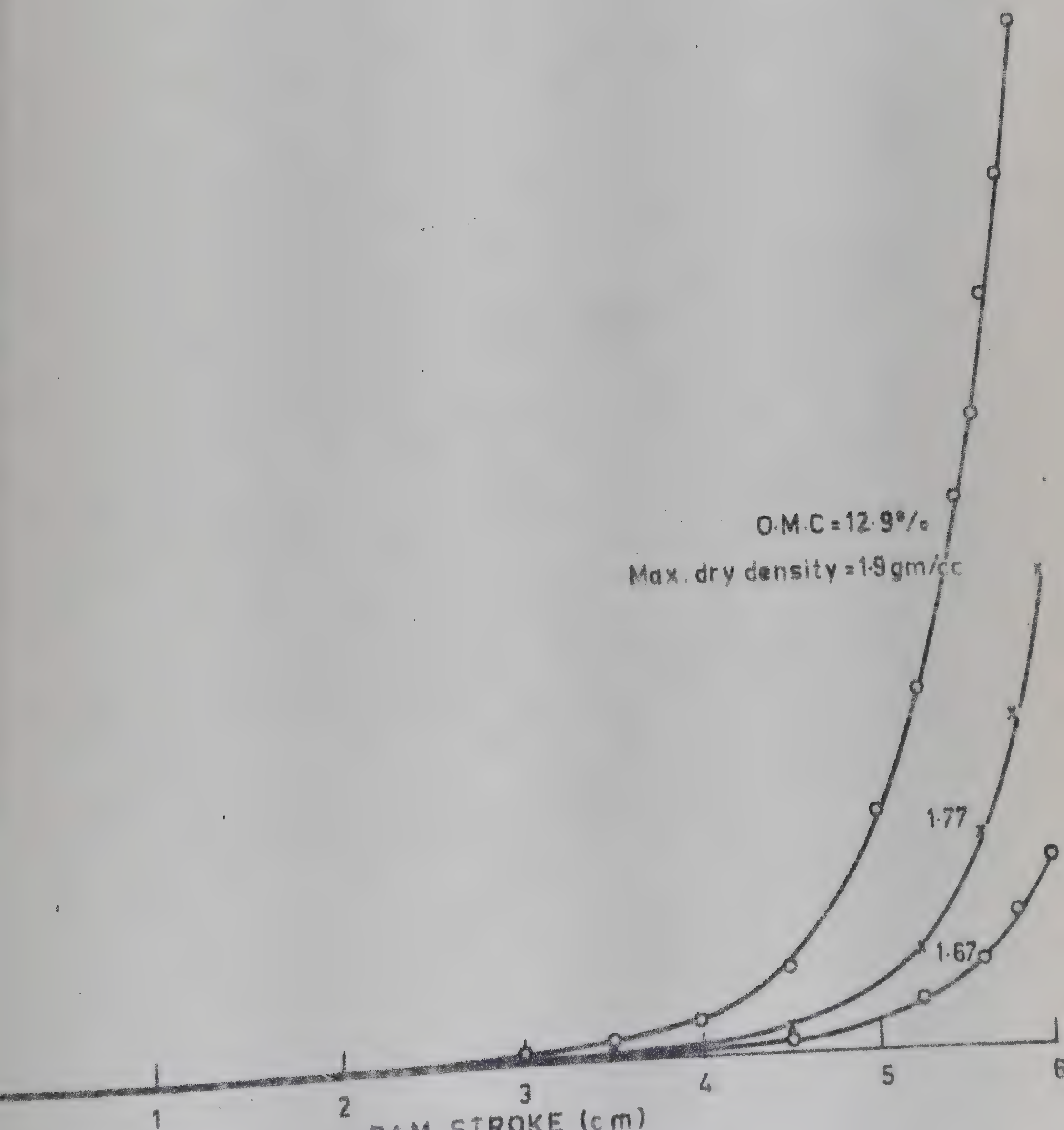


FIG · 2 - COMPACTION FORCE FOR SANDY SOIL

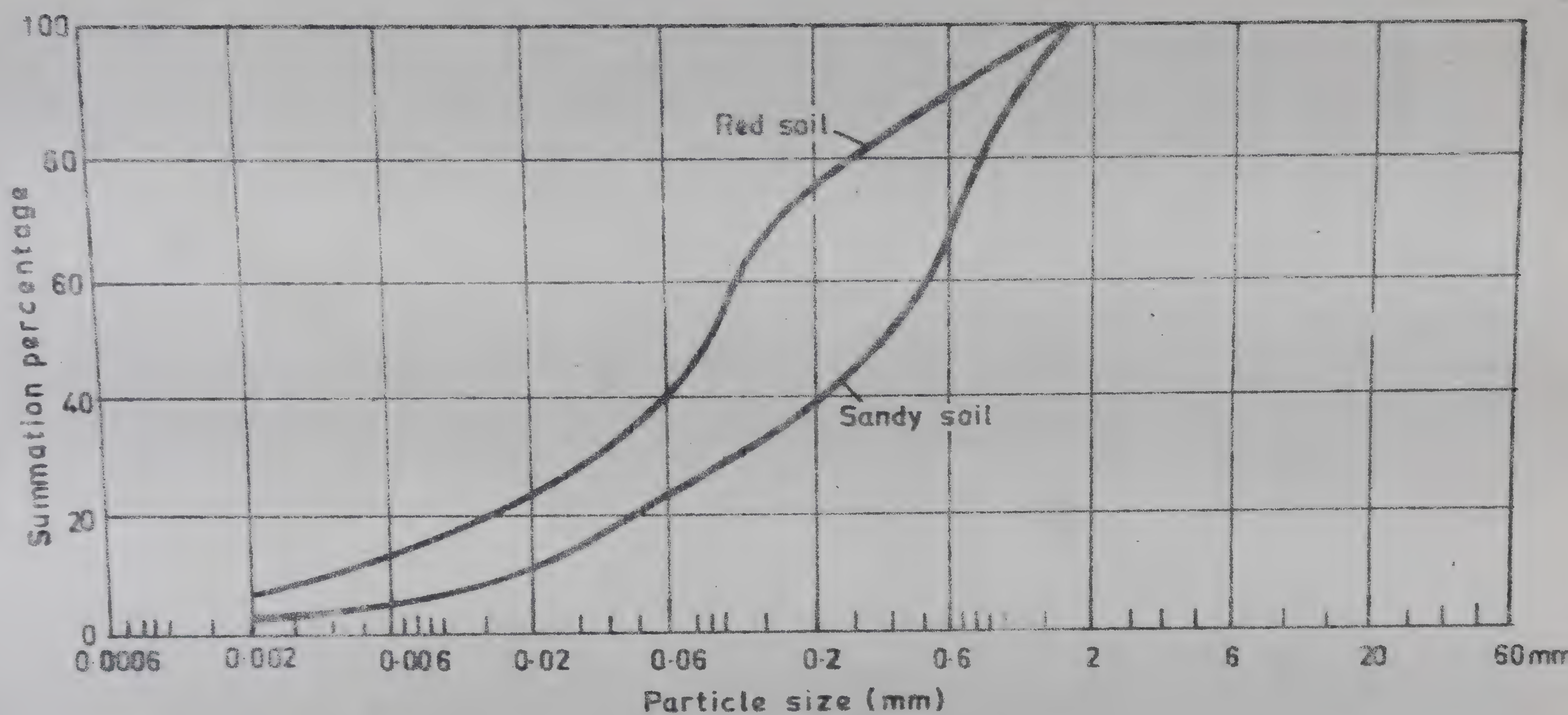


FIG 3 - PARTICLE SIZE DISTRIBUTION OF SOILS

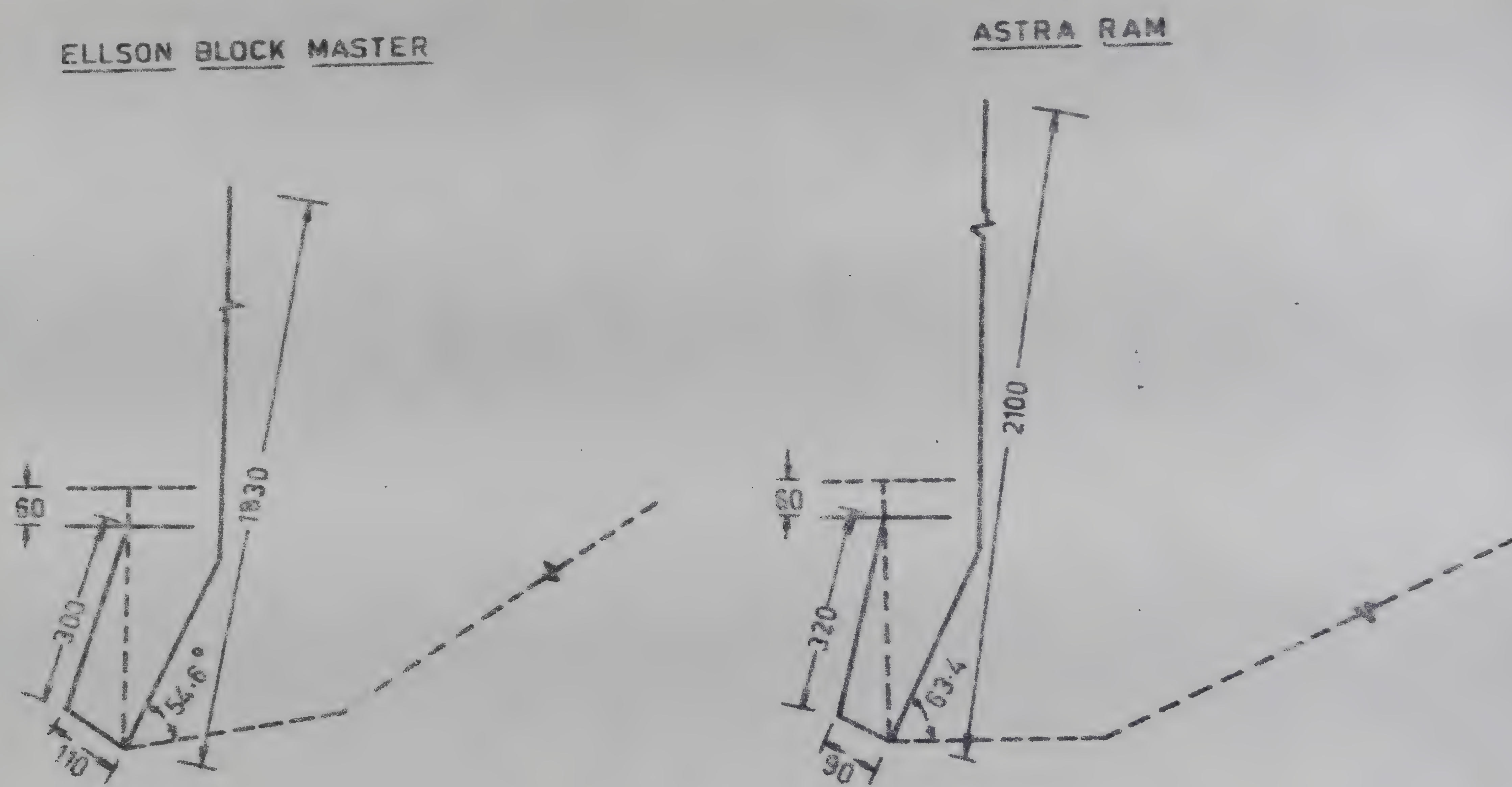


FIG.4 - TOGGLE MECHANISMS OF COMPACTION MACHINES

(all dimensions are in mm)

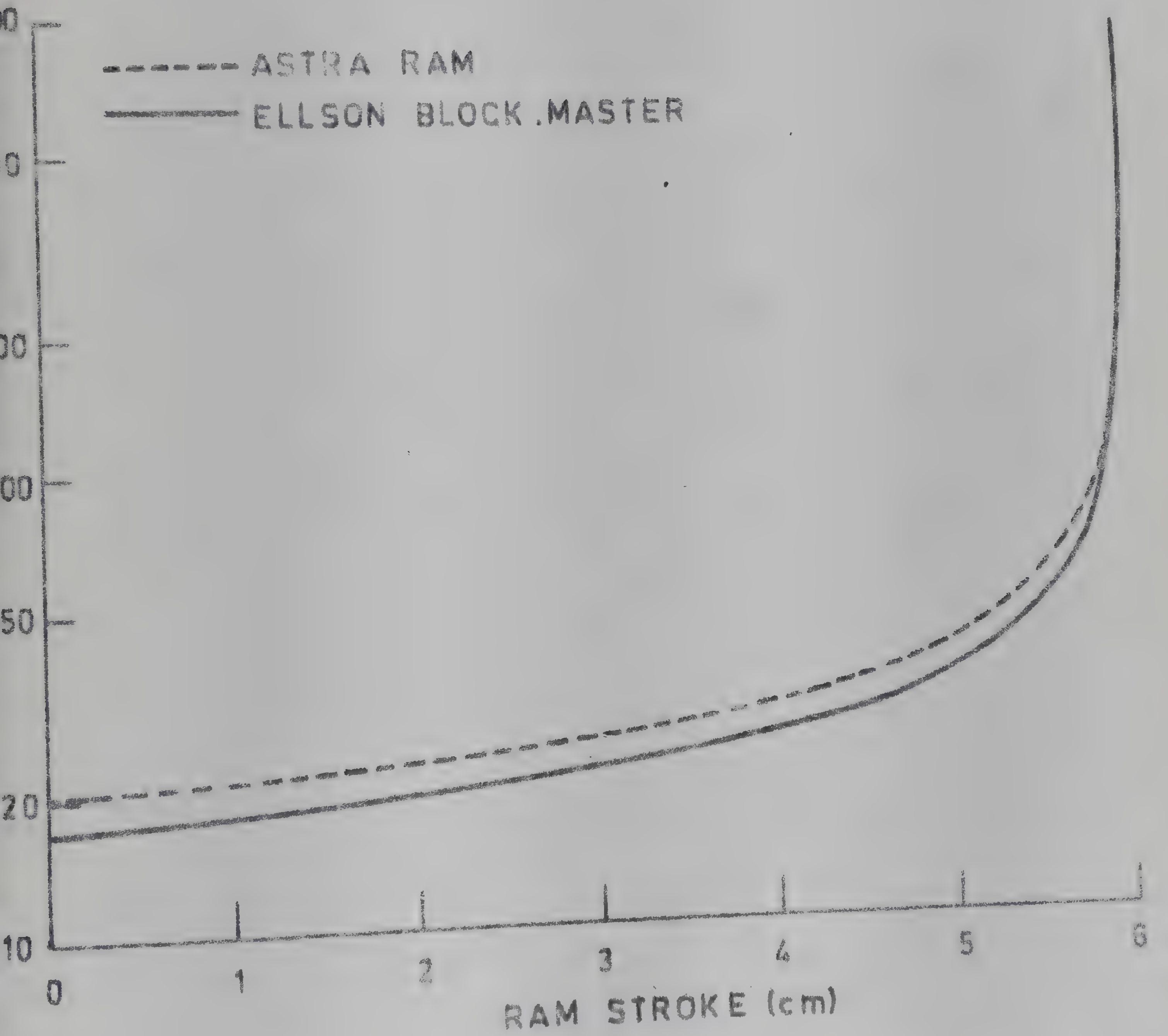


FIG 5 - FORCE AMPLIFICATION IN SOIL COMPACTION MACHINES

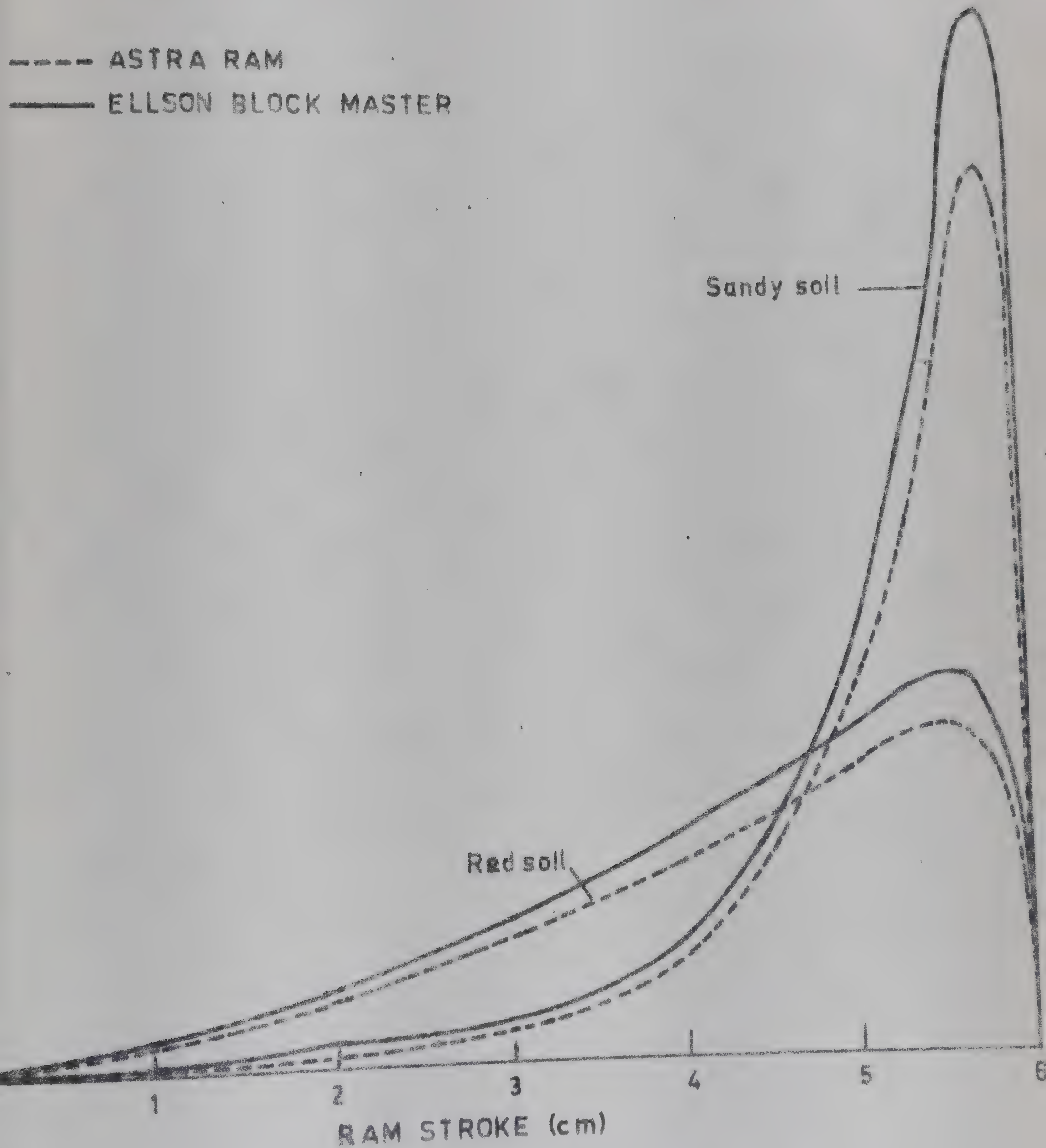
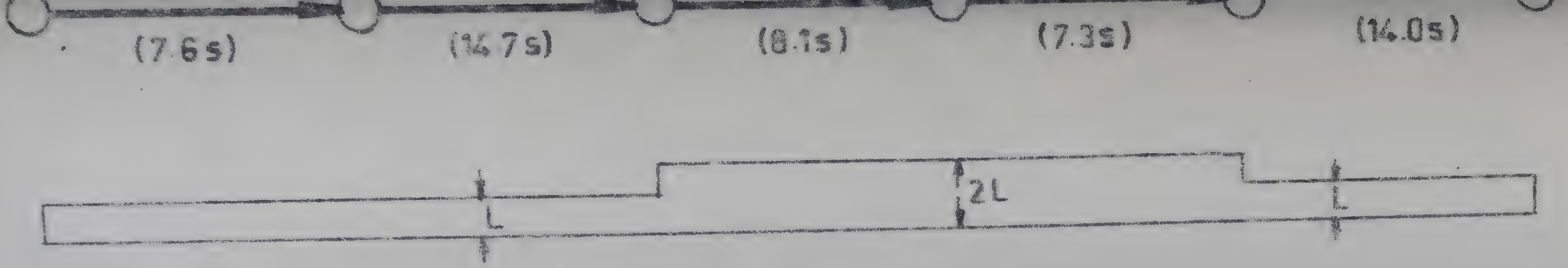
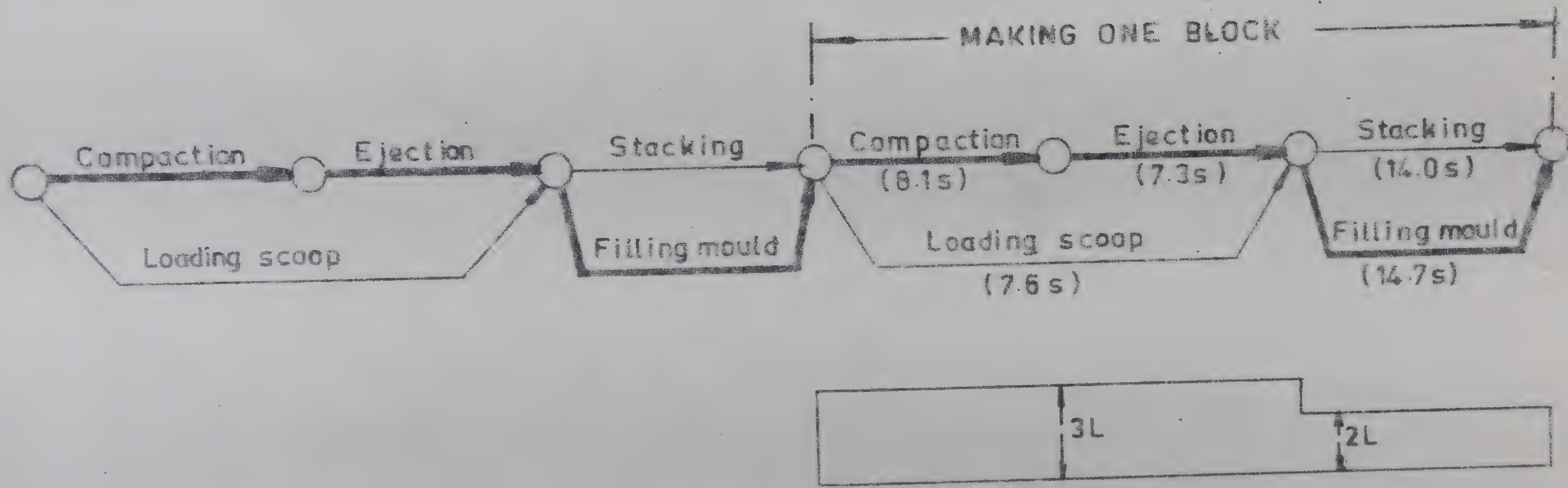


FIG.6-HUMAN EFFORT DURING COMPACTION FOR A 9kg SOIL BLOCK



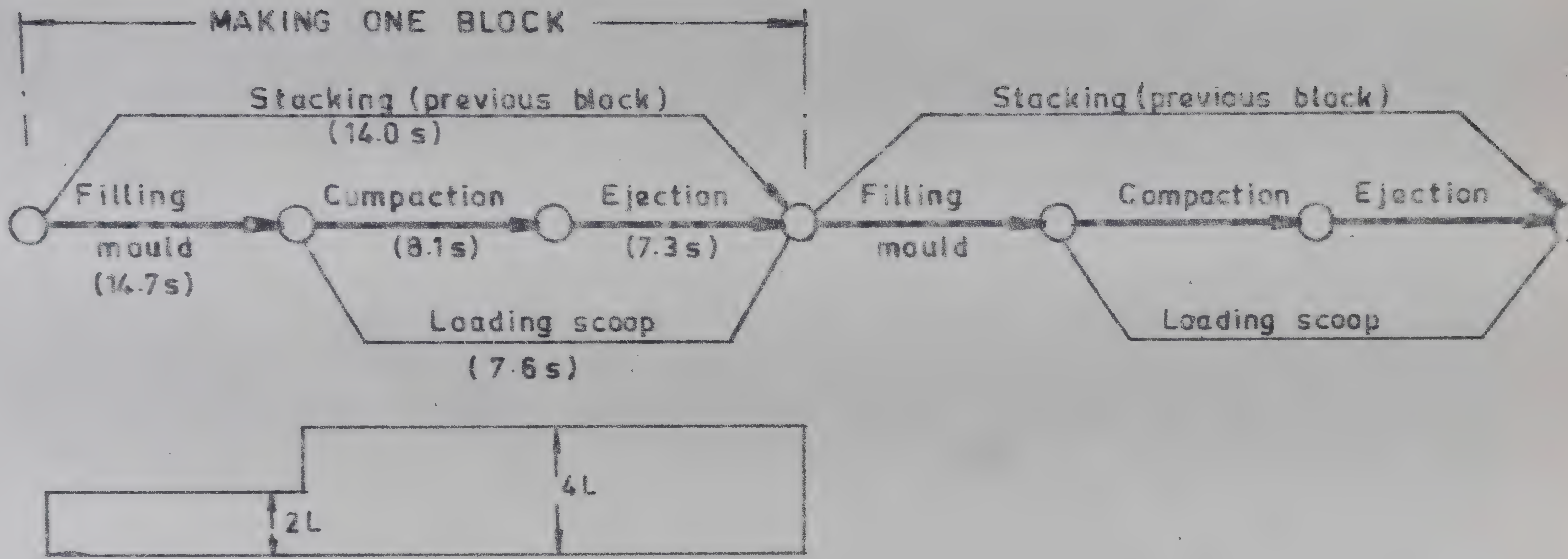
Total time per block = 51.7 seconds

FIG.7 ACTIVITY NET WORK AND LABOUR UTILISATION DIAGRAMS FOR MAKING ONE BLOCK WITH 2 LABOURERS



TOTAL TIME PER BLOCK = 30.1 seconds

FIG. 8. ACTIVITY NET WORK AND LABOUR UTILISATION DIAGRAMS FOR MAKING ONE BLOCK WITH 3 LABOURERS



TOTAL TIME PER BLOCK = 30.1 seconds

FIG. 9. ACTIVITY NETWORK AND LABOUR UTILISATION DIAGRAMS FOR MAKING ONE BLOCK WITH 4 LABOURERS

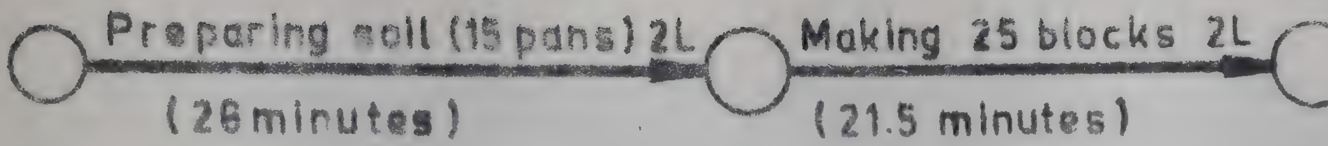


FIG. 10. ACTIVITY NETWORK WITH 2 LABOURERS

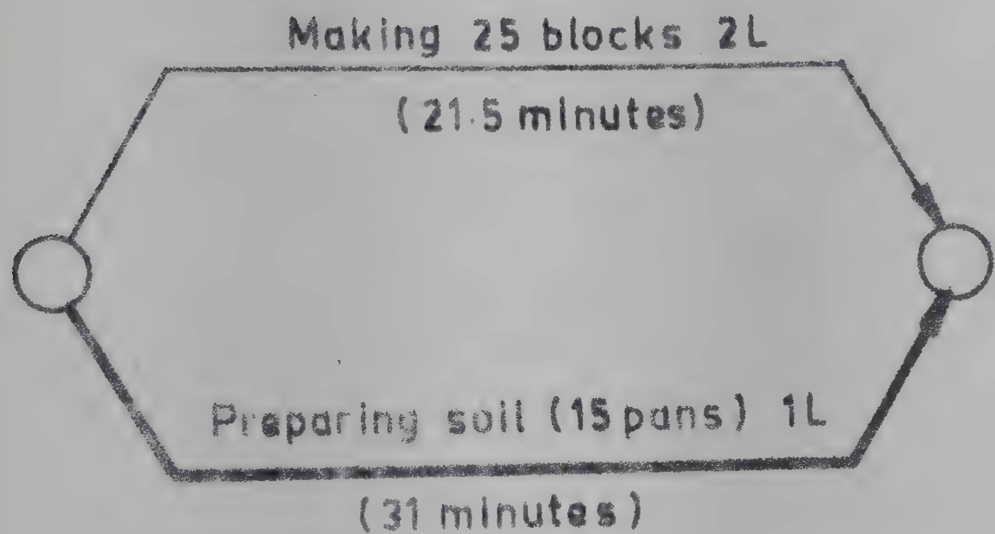


FIG. 11. ACTIVITY NETWORK WITH 3 LABOURERS

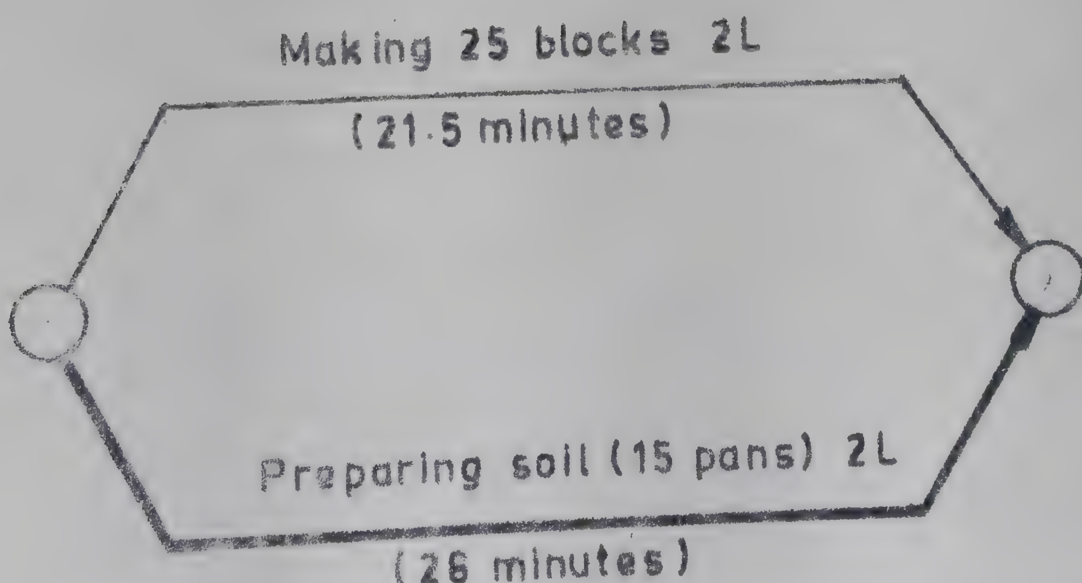


FIG. 12. ACTIVITY NETWORK WITH 4 LABOURERS

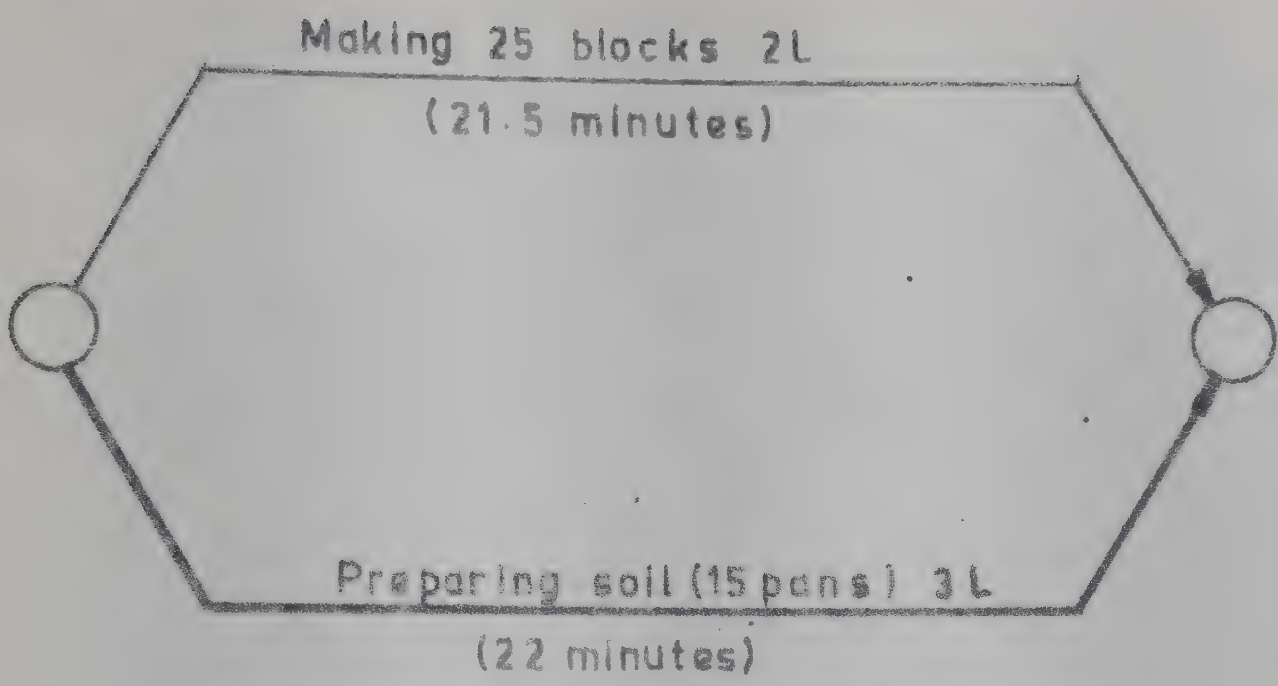


FIG. 13 ACTIVITY NETWORK WITH 5 LABOURERS

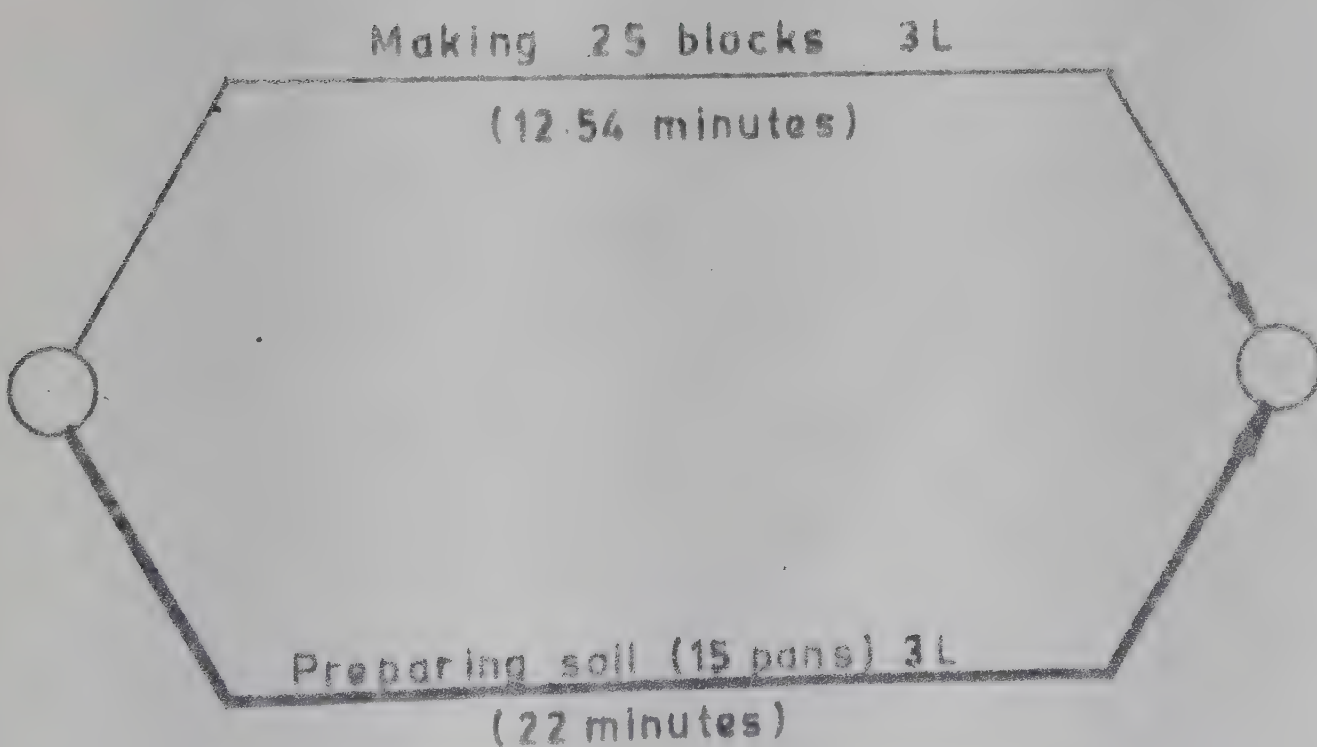


FIG. 14 ACTIVITY NETWORK WITH 6 LABOURERS

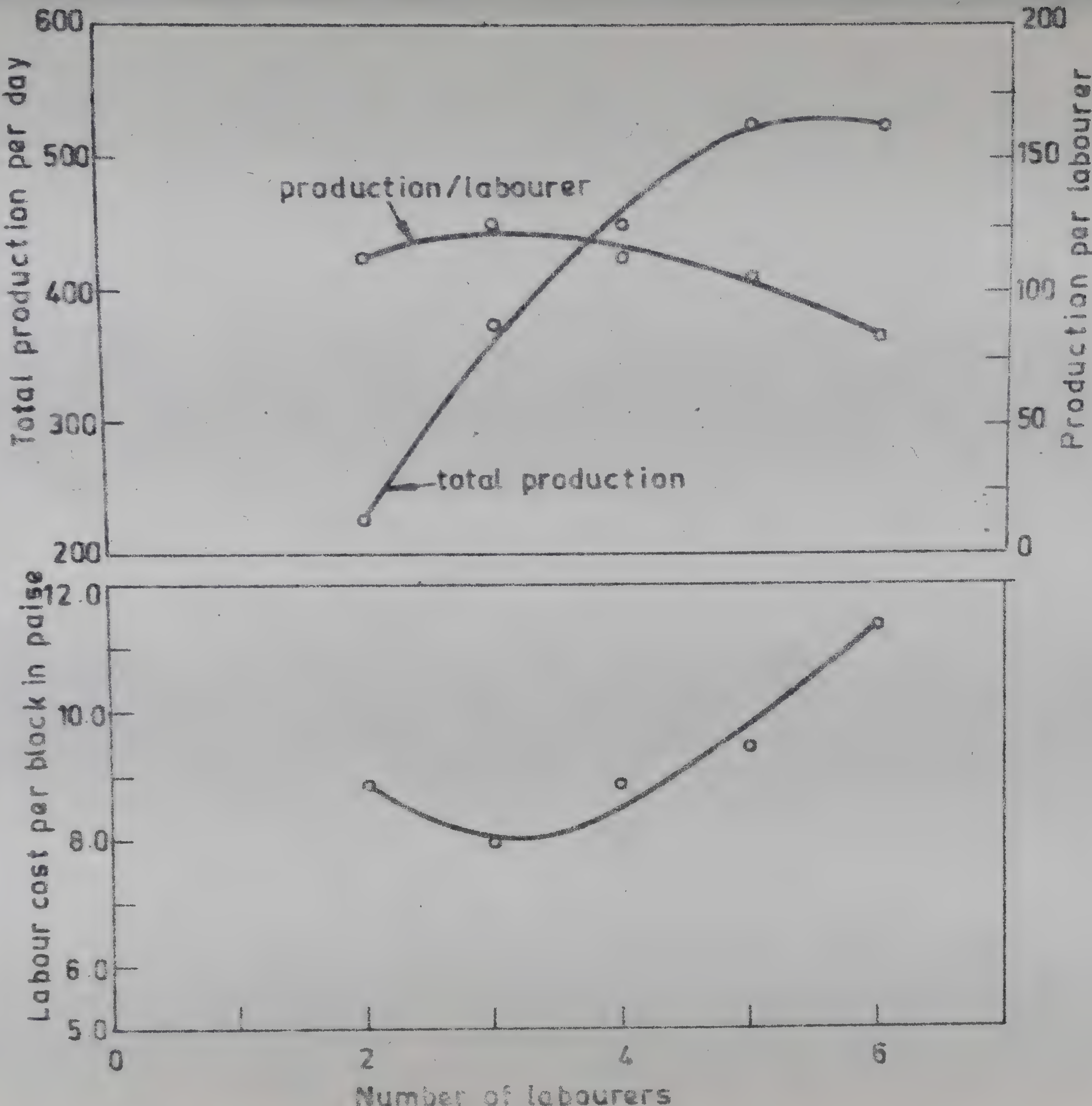


FIG.15. LABOUR AND BLOCK PRODUCTION

RAINFALL, RUNOFF AND USAGE PATTERNS

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Lecture No.8.1

1. Climate and rainfall:

Climate and rainfall in India are influenced by its tropical location, the presence of the Himalayas and the Western Ghats, the sea surrounding the southern part on three sides and by the fact that it is situated in the monsoon region, i.e., where the direction of wind changes with season.

Fig.1 shows the average dates of onset and withdrawal of the monsoons at different places in the Indian subcontinent (1). Rainfall begins (ignoring the "pre-monsoon" showers) in Sri Lanka during the last week of May and covers Tamil Nadu and half of Kerala, by 1st June, when the sun is already halfway across the Deccan. The southwesterly winds after producing rain in southeast India cross the Bay of Bengal, where they pick up moisture again, and blow into Burma and Bangladesh which receive rainfall around the same time. The southwest monsoon is thus distinguished by its two branches, named respectively the Arabian Sea Branch and the Bay of Bengal Branch.

Fig. 1 shows that the Arabian Sea Branch steadily advances northwards across peninsular India and covers the western state of Gujarat by the end of June. In the meantime, the Bay of Bengal Branch spreads over the northeastern states of India by the first week of June. The winds are deflected westwards by the Arakan hills of Burma and the Himalayas and this branch of the monsoon thereafter progresses in the western direction along the Gangetic Plain. By the middle of June, the two branches merge over Uttar Pradesh and progress towards Haryana and Punjab.

The amount of rainfall at various places on the Indian subcontinent depends on the Orographical features and the distance from the coast measured along the monsoon current. The Western Ghats force the Southeast monsoon winds upward, leading to moisture condensation and heavy rainfall on the West Coastal Plains. This loss of moisture results in a considerably lighter rainfall east of the Western Ghats. There is, in fact, a rain shadow effect in this area. This is illustrated in Fig.2 which shows the isohyetal lines connecting points of equal average annual rainfall. Parts of Gujarat, Punjab and Rajasthan as well as Pakistan receive much less rainfall than the neighbouring regions because the monsoon winds are obstructed by the Aravalli Hills, east of which there is good rainfall. The southern part of Assam receives very heavy rainfall again due to Orographic causes; the Khasi Hills (mean altitude 1500 m) catch the Bay of Bengal Branch in a relatively narrow valley and deflect it upward. As a result, the town of Cherrapunji in this region records the world's second highest annual average rainfall of 1142 cm. Heavy rainfall similarly occurs in the Outer Himalayan regions of Bhutan and Arunachal Pradesh.

On June 21, the sun begins its southward journey from the Tropic of Cancer, which runs a little north of the Deccan Plateau. By this date, the monsoon covers almost the whole of India. Rainfall ceases in northwest India around 1st September, by which time the sun is situated well to the south of Sri Lanka. The monsoon withdraws from India gradually

as shown in Fig.1, roughly in the same way as it advanced. Southeast India and Sri Lanka experience, because of the high pressure region situated on the cold Asian landmass to the north-east of India, a second bout of rainfall (the Northeast Monsoon) during the winter, which ends by the middle of December in India.

To summarise, the rainy season ranges from about 6 weeks during July - August in northwestern India to about 6 months during June - December in the southeast. The latter region receives about 50% of its annual rainfall during the Southwest Monsoon and the rest during the Northeast Monsoon (2). During the months from June to October, a number of depressions form over the Bay of Bengal and there is a high probability that a few of them will move inland across either the east coast into the Peninsula or the Orissa - Bengal coast into the Gangetic Plain (3). These moving depressions have a life of 4 - 5 days and can cover considerable distances in this interval. Depressions also form over the Arabian Sea, but very few are likely to move into India. Rainfall occurs over a wide area under the tracks of these depressions (upto about 500 km wide), normally of the order of 10 cm - 20 cm per day. Maximum rainfalls of 99 cm in 24 hours in Gujarat and 90 cm in 24 hours in Bihar have been recorded under these depressions, which contribute a significant proportion of the annual rainfall over an area extending from the northern coast of Andhra Pradesh to the Punjab Hills. Table 1 shows the number of depressions which moved inland, in different months, over a 69 - year period

from 1891 to 1960. It is seen that one depression each month can be expected to cross inland from the Bay of Bengal from June to October, sometimes more during July, August and September.

TABLE 1 NUMBER OF DEPRESSIONS MOVING INTO INDIA DURING 69 YEARS FROM 1891 to 1960

In the month of	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	De
From the Bay of Bengal	0	1	0	9	27	56	88	98	98	65	34	4
From the Arabian Sea	0	0	0	3	2	8	4	0	2	8	6	0

During April - May and October - November, when the Inter-Tropical Convergence Zone passes over the Bay of Bengal (4), heavy thunderstorms occur. Severe cyclones may cross the west coast causing devastation in the coastal regions.

Table 2 shows the mean rainfall distribution in India according to region and season as well as the mean annual rainfall. Rainfall in any individual year may vary on either side of these figures. Generally speaking, variations from the mean are lower in higher rainfall areas, and vice versa[6]. In the Arunachal Pradesh area, the standard deviation is about 15% while in the semi-arid Rajasthan region, it is of the order of 60%, reaching 80% in the desert region[3]. Fig. 3 shows the average number of rainy days (days on which the

rainfall is at least 2.5mm) per year in different regions.

TABLE 2. - RAINFALL DISTRIBUTION IN INDIA

ate	Meteorological Sub-Division	Average Rainfall in cm during				Average annual Rainfall, cm
		Jan-Feb	Mar-May	June-Sept	Oct-Dec.	
1	2	3	4	5	6	7
ra desh	Coastal region	2	7	56	34	99
	Telengana	1	7	78	11	97
	Rayalaseema	1	7	39	19	66
m, achal esh, alaya, land, pur, ura, ram	North	6	59	151	17	233
	South	5	64	162	25	256
r	Plateau	5	10	111	10	136
	Plains	3	7	104	8	122
at	Gujarat	-	1	84	4	89
	Saurashtra & Kutch	-	-	55	4	59
na hi	Haryana & Delhi	6	4	60	5	75
& ir	Jammu & Kashmir	10	18	36	5	69
a	Kerala	4	48	166	54	272
a sh	East	4	6	122	8	140
	West	2	3	96	6	107
ash- Goa	Madhya	1	5	53	11	70
	Marathwada	1	3	65	9	78
	Vidarbha	2	4	97	8	111
	Konkan & Goa	-	4	222	13	239
taka	Coastal Region	-	16	295	23	334
	Interior North	1	7	58	13	79
	Interior South	1	16	42	22	81
a	Orissa	4	12	120	19	155

contd.

1	2	3	4	5	6	7
Punjab	Punjab	6	5	49	4	64
Rajasthan	East	1	2	63	4	70
	West	1	2	26	1	30
Tamil Nadu	Tamil Nadu & Pondicherry	6	12	27	53	98
Uttar Pradesh	East	4	4	96	7	111
	West	6	4	90	5	105
West Bengal	Sub Himalayan	3	41	219	17	280
	Gangetic	4	18	113	16	151
Himachal Pradesh	Himachal Pradesh	10	13	118	12	153
Islands	Andaman, Nicobar and Other Bay Islands	14	49	160	72	295
	Lakshadweep & Other Arabian Sea Islands	4	20	99	34	157

Due to the seasonal concentration of the rainfall throughout the country, techniques for storage of rain water have evolved. These techniques vary from one region to another, depending on the terrain, soil types etc.

2. Rivers of India:

Part of the water which falls as rain is absorbed by the soil under the action of gravity and capillary forces, and is held as soil moisture and ground water. Of the rest, some water is intercepted by leaves of the vegetal cover and some flows on the surface. Part of this water may percolate into

the ground or get evaporated. The remaining water flows in streams and rivers as runoff towards their ultimate destination, which could be the sea, reservoirs or canals and agricultural fields, where further percolation, consumption, evaporation, evapotranspiration etc. will take place. Estimating the flow of the rivers (the runoff) from rainfall and other parameters has long been the subject of investigation. Actual measurement of the flow has been done only at a few stations. These measurements have been correlated with rainfall. Where no measurement is available, Khosla's formula has been used extensively in India:

$$R_m = P_m - 4.8\ T_m$$

where R_m, P_m and T_m are respectively the monthly mean runoff (mm), Precipitation (mm), and temperature (°C) of the region ($T_m > 5°C$). The mean annual flow can be calculated by summing the mean monthly flows.

India has a large number of rivers draining into the Arabian Sea or the Bay of Bengal, apart from a few desert rivers which flow for a small distance and disappear in the sands of the Thar desert. 11 of the former each carry more than 10,000 million m^3 of water on an average every year, the two biggest being the Brahmaputra and the Ganga respectively. Next is the Indus, on the banks of which an ancient civilisation flourished. The estimated total annual average discharge carried by these 11 rivers is[3] $1.56 \times 10^{12}\ m^3$. 47 other rivers are estimated to carry a total of $1.23 \times 10^{11}\ m^3$,

a number of minor rivers 1.17 X 10^{11} m^3 and the desert rivers 10^{10} m^3 of water each year on an average. The total average annual discharge carried by the Indian rivers is thus 1.81 X 10^{12} m^3. (of the Amazon, which alone discharges about 6.3 X 10^{12} m^3 of water per year). The total annual flow in all the rivers of the world is estimated to be 27.14 X 10^{12} m^3, so that the Indian rivers account for 6.7% of the total runoff, draining 2.2% of the land area of the world.

The three biggest rivers, the Ganga, Brahmaputra and the Indus are fed by snow melting in summer, and hence carry substantial discharge throughout the year, though the peak discharge occurs during the monsoon. The other rivers being purely rainfed, either dwindle or completely dry up during the post-monsoon months.

3. <u>Comparative values of surface flows</u>:

Table 3 gives the estimated values of surface flow for India and some selected countries, together with other statistical information.

contd..

TABLE 3. AREA, POPULATION AND SURFACE FLOW OF WATER OF SOME COUNTRIES.

Country	India	Sri Lanka	Pakistan	Israel
Area 000 Km^2	3276.	65.6	803.9	20.7
Arable land 000 Km^2	1946	16	303.5	Not available
Population (1971) millions	548	13	64.9	3.2
Density of population per Km^2	167	198	80.7	155
Estimated total surface flow per year, million m^3	1810000	432000	175000	590
Surface flow per capita per year m^3	3303	33231	2696	184

India has a fairly good surface water availability on a per capita basis. In comparison, Israel has one of the world's lowest per capita surface water availability. Within India, the per capita distribution of surface water runoff varies from region to region.

4. <u>Water usage technologies</u>:

Most of the water (more than 90%) is used for irrigation. The technologies used in the utilisation of water for irrigation have evolved differently in different regions depending on the regional physiography, soil characteristics etc. In flat regions where large rivers flow, long canals have extensively been used. In rolling country, short canals from small reservoirs (tanks) built across small streams have developed. In hilly terrain, ground water recharge by surface storage combined with dug wells supply the irrigation water. Where soil is water-retentive and the land is flat, a soil-water storage cum irrigation technique has evolved. These technologies are described in succeeding lectures.

Many parts of India suffer both extremes in water availability, namely floods and droughts, often during the same year, because of the seasonal nature of rainfall and inadequate storage Even in the west coast of peninsular India, where some places receive near the highest annual rainfall in the world, a drought situation exists from February to June each year. Storage of water for using during dry periods has therefore been practiced for centuries all over the country.

8.1

5. <u>Soil erosion as a consequence of runoff:</u>

Soil is a precious resource for any community. It is estimated that a hundred years are required for the formation of one cm. of topsoil. In our country, due to the pre-monsoon weather, soil is loosened up, and the often violent rainfall pries more soil particles out. The surface runoff carries this soil into the streams. Cultivation, overgrazing and deforestation hasten this process of soil erosion. The small gullies formed initially in a deforested or a de-grassed region get widened and deepened during each subsequent rainfall. Once the few centimetres of top soil, which only can sustain vegetation in many regions, are removed, it is extremely difficult to arrest the erosion process. Low check-dams across gullies, which trap the eroded soil from above, can sometimes help. Besides loss of topsoil, soil erosion results in the sitting up of tanks and reservoirs, reducing their lives. Some relevant figures in this regard are given in the next lecture.

8.1

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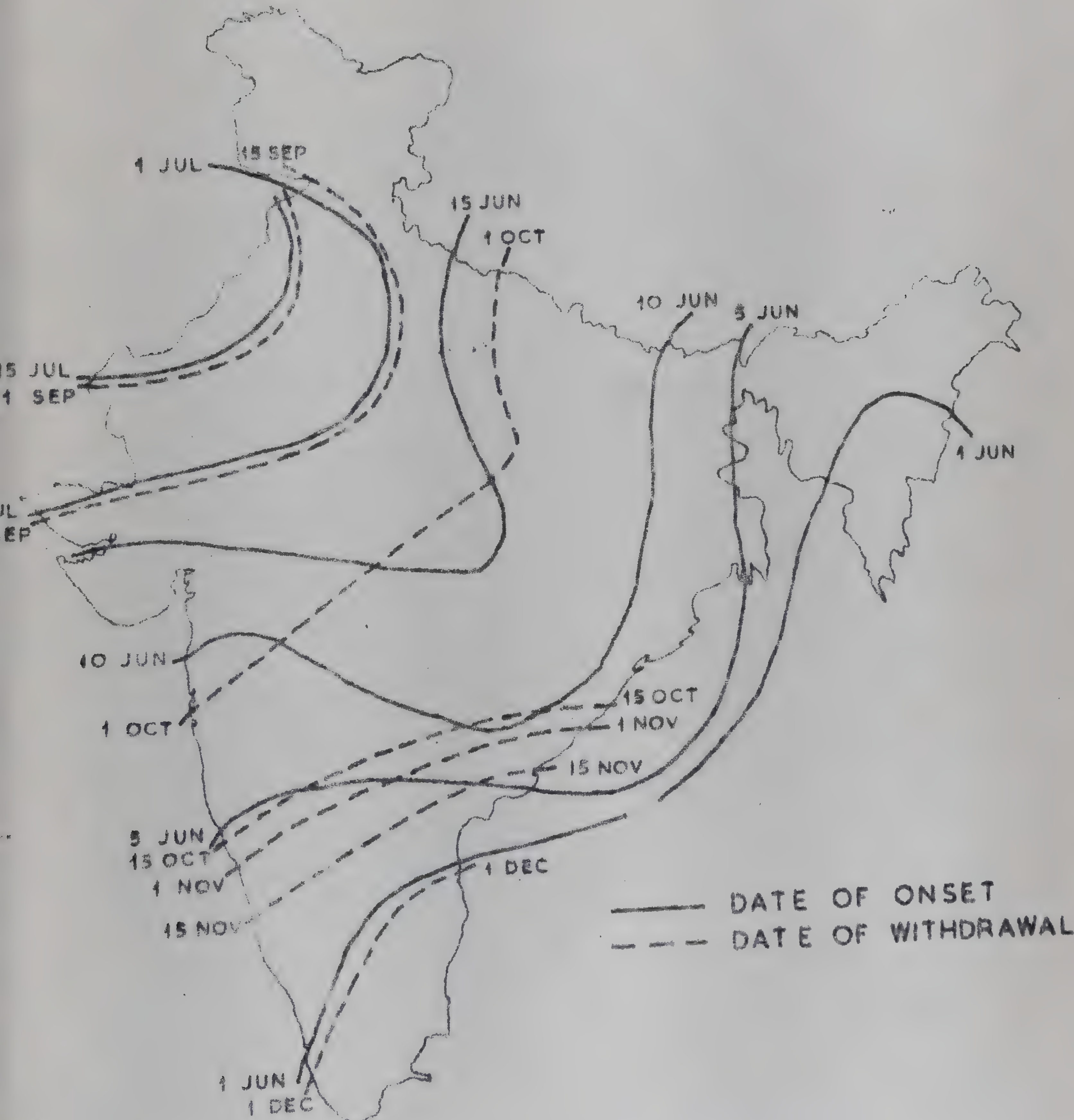

FIG. 1 - MONSOON DURATION IN INDIA

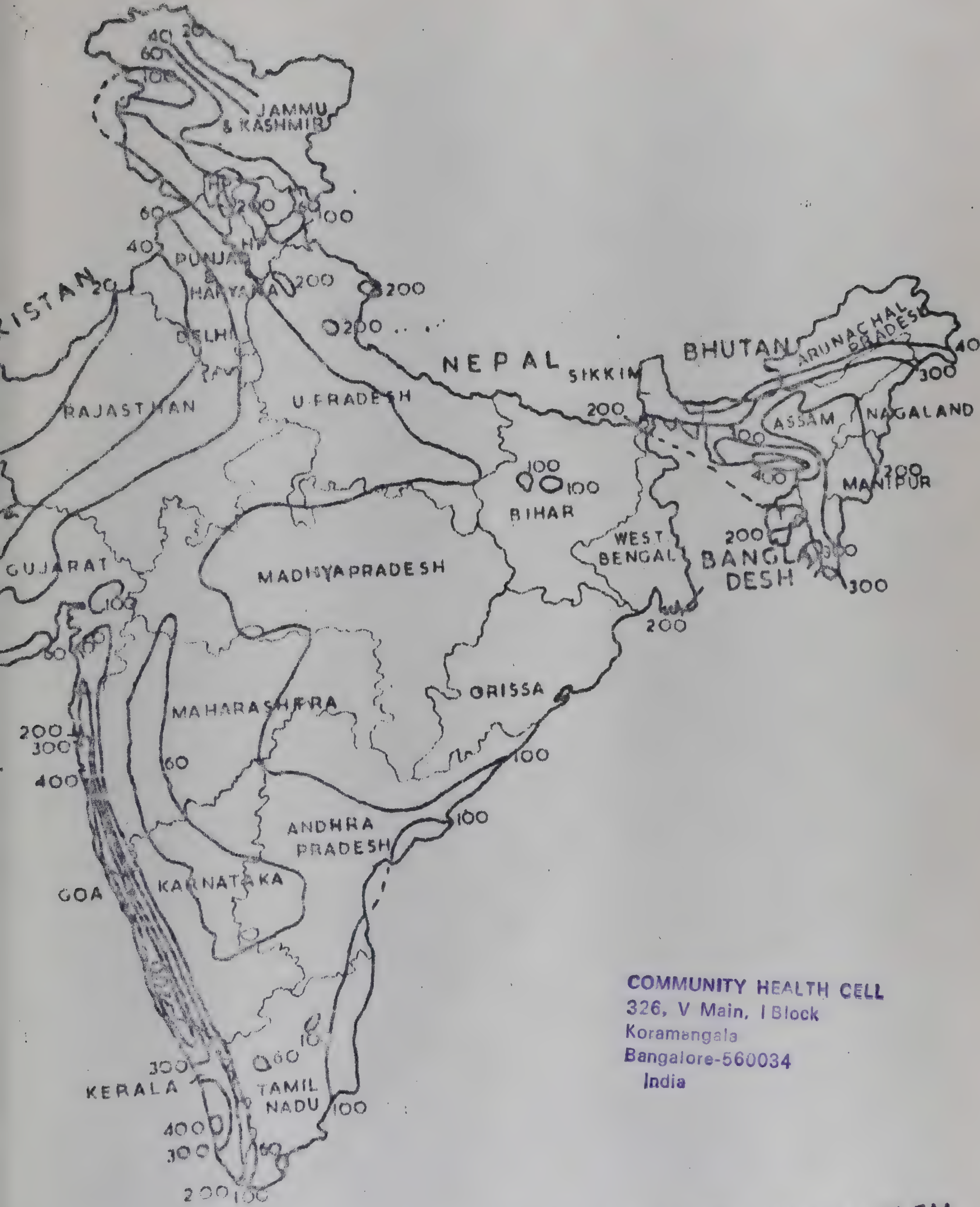

FIG . 2 . ANNUAL AVERAGE RAINFALL IN INDIA, IN CM

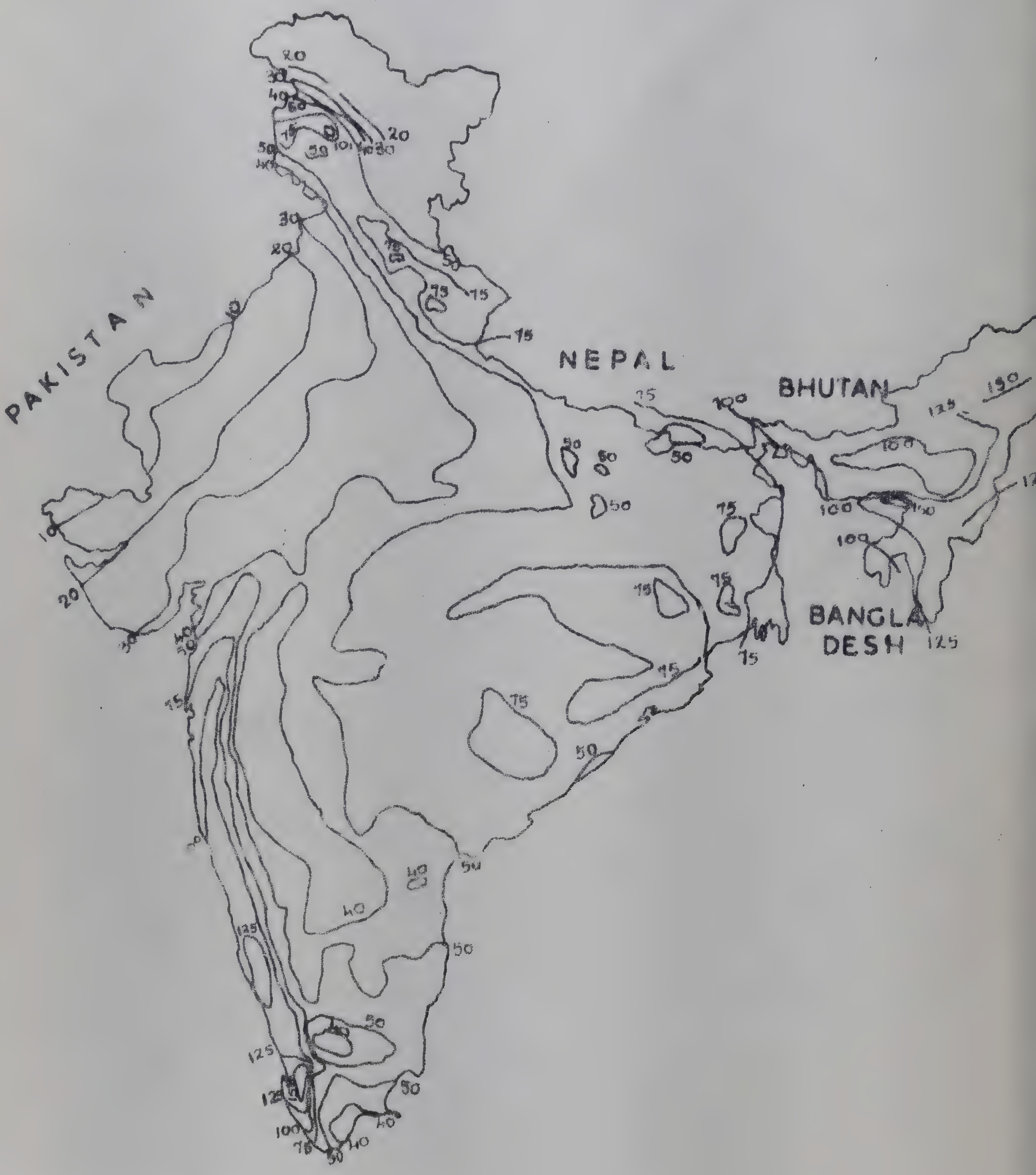

FIG. 3 : NUMBER OF RAINY DAYS IN INDIA